Predicting short-duration, high-intensity rainfall in Saudi Arabia.

Hassan Abdullah Al-Khalaf

Civil Engineering

1997

Abstract

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From the model curves obtained for each station, the average coefficients were calculated for each region. The average values obtained from rainfall data intensities and from coefficients were tabulated and the model showing the least error was chosen as the representative model for that region.

Predicting Short – Duration High - Intensity Rainfall in Saudi Arabia

by

Hassan Al-Khalaf

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

CIVIL ENGINEERING

June, 1997

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PREDICTING SHORT - DURATION , HIGH - INTENSITY RAINFALL IN SAUDI ARABIA

SUBMITTED BY
HASSAN AL - KHALAF

June , 1997

KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS

Dhahran 31261, Saudi Arabia

CIVIL ENGINEERING DEPARTMENT

This Master of Engineering Report written by HASSAN ABDULLAH AL-KHALAF under the direction of his Advisor and approved by his Report Committee, has been presented to and accepted by the Dean of the College of Graduate Studies, in partial fulfillment of the requirements for the degree of MASTER OF ENGINEERING IN CIVIL ENGINEERING.

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Dean, College of Graduate Studies

Date: 30-12-97

This is Dedicated to

My Wife
and
to my Children

ACKNOWLEDGEMENTS

I would like to express profound thanks and praise to ALLAH, Almighty, the Most Merciful and the Most Gracious, for enabling me to complete this work. Peace be upon His Prophet.

Profound thanks are due to my wife for her never ending love, understanding and encouragement. My children were a constant source of joy and delight and I acknowledge their contribution with much pleasure.

I wish to express my appreciation to my adviser Dr. Achi M. Ishaq for his invaluable guidance, and help during the course of this work. Acknowledgement is also due to the other members of my committee for their valuable contributions during the course of this study.

I am grateful to the Civil Engineering Department of King Fahd University of Petroleum & Minerals, for providing me with a warm atmosphere and continuous support.

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ABSTRACT

Estimation of return period of high-intensity rainfalls is very important in several engineering aspects, such as design of contour drains, dams, road culverts, airfield drainage, storm sewers in urban areas, and flood or sediment control dams in water catchments.

Two scientist from USA, **Hershfield** and **Bell** (1969), proposed Two relationships for estimating rainfall depths in USA they claimed that those relations are applicable in the whole world.

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In order to do that, rainfall data was obtained from the Ministry of Agriculture and Water in Saudi Arabia for 28 stations. It was then tabulated and analysed using the computer program **Gumbel 2** in order to obtain the intensity / duration / frequency curves representing 9 operational regions of the kingdom (having at least 10 -years of records) .

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The same analysis was performed for calculating the ratios of intensities corresponding to the 2, 5, 25, 50, and 100-year value to that of the 10-year value for the 60 min duration. Then the results were tabulated and compared to **Bell's (1969)** ratios. Model curves were also obtained using regression analysis methods.

The results showed that the short duration / high intensity rainfall was far from the universal relationship suggested by **Bell** or **Hershfield**.

The average values of the rainfall data were calculated for each region in the kingdom and analysed using **Gumbel 2** program to produce average intensity/duration data. From these data, model curves representing each region were obtained . From the tables constructed , the average densities were calculated for each region and model curves were obtained as before.

From the model curves obtained for each station , the average coefficients were calculated for each region . The average values obtained from rainfall data, intensities and from coefficients were tabulated and the model showing the least error was chosen as the representative model for that region.

خلاصـــة

ان تقدير عودة فترة الكثافة العالية لهطول الأمطار أمر هام جداً بالنسبة للعديد من الجوانب الهندسية مثل تصميم المصارف الكنتورية والسدود ومجاري التصريف تحت الطرق وتصريف المياه في حقول الطيران ومصارف مياه الأمطار في المناطق الحضرية والسدود للسيطرة على الفيضانات أو الترسب في مستجمعات المياه.

اقترح عالمان أمريكيان وهما **هيرشفيلد و بيل (١٩٦٩)** علاقتين لتقدير عمق هطول الأمطار في الولايات المتحدة وإدّعيا بأن هاتين العلاقتين تنطبقان على كل العالم.

اننا نحاول في هذه الدراسة أن نختبر إمكانية تطبيق هاتين العلاقتين في المملكة العربية السعودية.

ولفعل ذلك تم الحصول على بيانات عن هطول الأمطار من وزارة الزراعة والمياه في المملكة العربية السعودية من ٢٨ محطة. بعد ذلك تمت جدولتها وتحليلها باستخدام الحاسب الآلي برنامج **غامبل ٢** وذلك من أجل الحصول على منحنيات الكثافة/ الفترة/ التردد التي تمثل الأقاليم العاملة للمملكة (لها سجلات ١٠ سنوات على الأقل).

تم تخطيط مجموعة من المنحنيات باستخدام بيانات الكثافة/ الفترة/ التردد لتكون أساساً للتحليل. تم عمل جداول تمثل معدلات الكثافة الى عمق ٦٠ دقيقة لهطول الأمطار للثماني والعشرين محطة. من بيانات الكثافة/ الفترة يتم حساب معدلات كثافة فترات العودة لخمس وعشرين عاما الى ١٠ سنوات بالنسبة لفترات ١٠ و ٦٠ و١٢٠ دقيقة ويتم جدولتها. تمت المقارنة في نفس الجداول بين المعدلات التي تم الحصول عليها وتلك الخاصة ببيل (١٩٦٩). تم الحصول على منحنيات نموذجية بواسطة التحليل التراجعي لكل محطة أيضاً باستخدام بيانات الكثافة/ الفترة.

تم عمل نفس التحليل لحساب معدلات الكثافات المطابقة لمقادير ٢ ، ٥ ، ٢٥ ، ٥٠ ، ١٠٠ سنة والمطابقة لمقدار ١٠ سنوات لفترة الستين دقيقة. ثم تمت جدولة النتائج ومقارنتها بمعدلات **بيل** (١٩٦٩). تم أيضا الحصول على منحنيات نموذجية باستخدام طريقة التحليل التراجعي.

أظهرت النتائج أن هطول الأمطار ذات الفترة القصيرة / الكثافة العالية بعيد عن العلاقة العالمية التي اقترحها **بيل** أو **هيرشفيلد**.

تم حساب متوسط قيم بيانات هطول الأمطار لكل منطقة في المملكة وتم تحليله باستخدام برنامج **غامبل ٢** لإعطاء بيانات متوسط الكثافة/ الفترة. تم الحصول من هذه البيانات على منحنيات نموذجية تمثل كل منطقة. ومن الجداول التي تم عملها تم حساب متوسط الكثافات لكل منطقة كما تم الحصول على منحنيات نموذجية كالسابقة.

من المنحنيات النموذجية التي تم الحصول عليها لكل محطة تم حساب متوسط المُعاملات لكل منطقة. تمت جدولة متوسط القيم الذي تم الحصول عليه من بيانات هطول الأمطار والكثافات ومن المُعاملات وتم اختيار النموذج الذي أظهر أقل خطأ على أنه يمثل المنطقة.

Chapter 1

INTRODUCTION

Estimation of return period of high-intensity rainfalls is very important in several engineering aspects, such as design of contour drains , dams, road culverts, airfield drainage, storm sewers in urban areas, and flood or sediment control dams in water catchments .

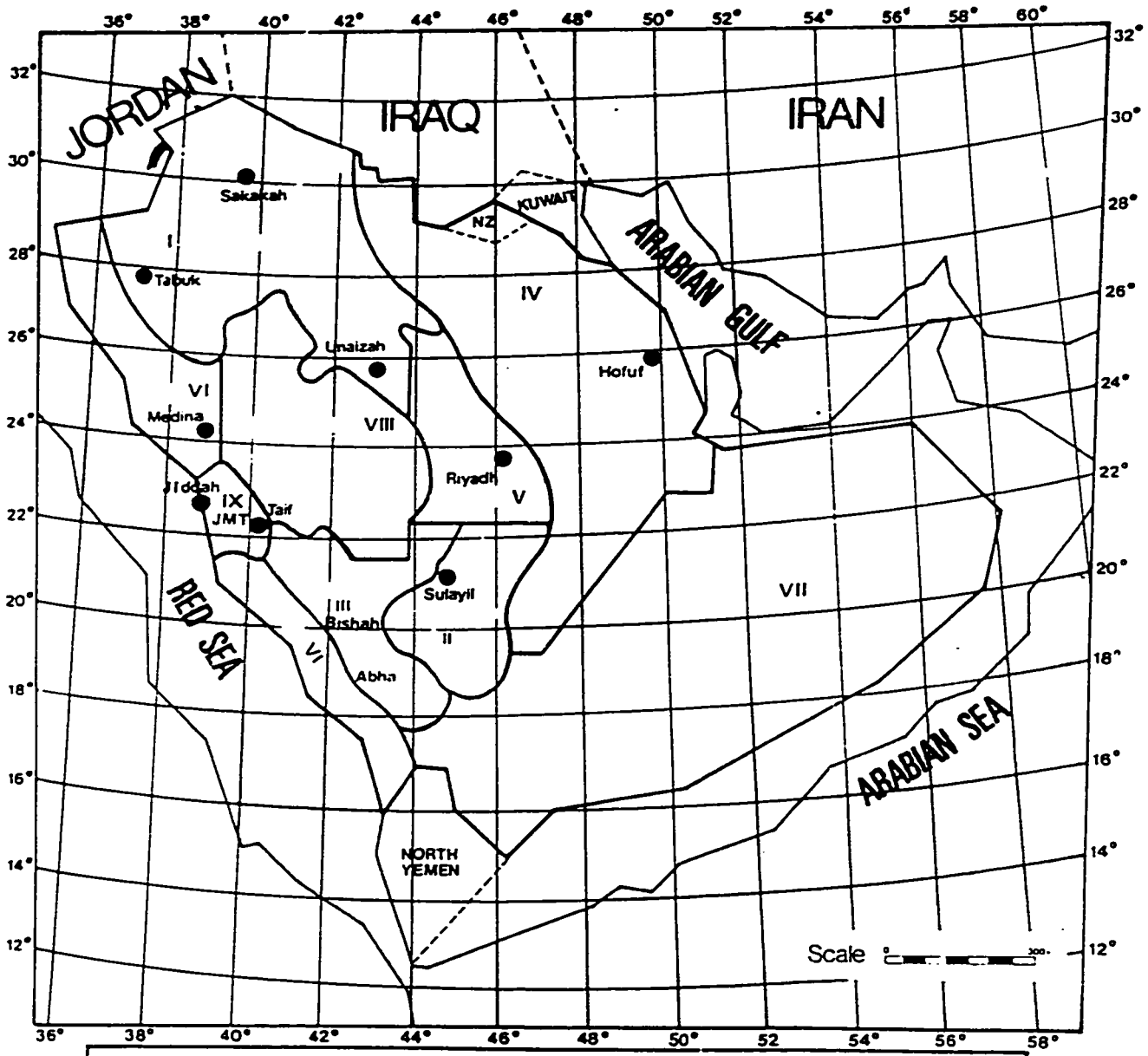
It is important to emphasize that in reality there are two types of intensity: The first one is intensity for long durations which is easily gauged (daily or hourly) , and the second one is for durations of 2≤ hours, which is difficult to gauge. Data associated with the letter is deficient in many parts of the world, because its control requires continuous reading of rain gauges which have been widely available only in the last decade . Moreover, estimation of short - duration rainfall has more significance because of its effect on small projects.

For engineering project design it is important to have an estimate of at least 50 years of return period .

Most countries nowadays have at least 10-years of return period or frequencies ; in such cases there is a need to extrapolate from 10 to 50 years, which needs empirical relations where there is a large uncertainty.

In this paper the analysis of rainfall data for 28 stations representing 9 operational regions (see **Fig. 1**) of the kingdom of Saudi Arabia except area **VII** (which is **Rub Alkhli**) is presented.

The main objective of this analysis is to predict high intensity - low duration relationship and compare it with that proposed by two scientists (**Hershfield** and **Bell**)(4). Another aim is to develop a model for each station and then to calculate the average values for each area (region) using model coefficients , average intensities, and average rainfall data for each region. The best model is then chosen as a representative model for that region.



Kingdom of Saudi Arabia

Ministry of Agriculture and Water Hydrology Division

Area I Tabuk, Sakakah

Area II Sulayil

Area III Bishah, Abha

Area IV Hufuf

Area VIII Unaizah

Area IX (J.M.T.) Jiddah, At Taif

Figure I: Operational Areas and Field Offices

Chapter 2

LITERATURE REVIEW

2.1 Choosing Data :

The principle of choosing the data is based on the concept of demarcating the highest rainfall depth for a given duration during the entire rain duration(1). For example if 3 mm. is the rainfall depth for the first 10 min. and 4 mm. for the next 10 min. then for the purpose of setting up the extreme value distribution 4 mm. is taken as the depth for duration of 10 min. So it was chosen as the annual basic for all durations.

2.2 Homogeneity :

Homogeneity in hydrology can be determined statistically with respect to time or space. **Time homogeneity** happens when the same events in a certain series occur at all times ; this in reality doesn't exist. **Space Homogeneity** means that hydrologic events at all places in an area are equal, with a degree of tolerance.

Statistical regional analysis can be used to obtain homogeneous areas, such as the method adopted by **Langbein** (5) which can be summarized as follows :

a) Put all stations in each area together.

b) List data for the maximum rainfall intensity in each year for durations of 10,20,30,60, and 120 min.

c) Data collected in (b) are analysed using the computer program (**Gumbel 2**), in order to obtain Intensity - frequency - duration relationships (IDF) .

d) A set of curves is constructed on **Gumbel** paper for each area. Then the 10-year and the 2.33 - year intensities are determined.

e) For each area and duration the value of 10-year intensity by the 2.33-year intensity is calculated , and their average value is obtained.

f) The average value from (e) is entered in the curves constructed in (d) to obtain a return period for each duration.

g) For each duration, the standard deviation is calculated as follows :

$$S = \frac{(Q - Q_a)}{1.305} \quad \text{.....(2-2-1)}$$

where Q = The average 10 - year value .

Qa = The average 2.33-year value .

h) Having calculated (S), a set of points representing all stations in each area are marked using the return period obtained from (f) vs. the number of years of records for each station, resulting in is so called control curves . These control curves are obtained as follows :

$$R_m^2 = \pm \frac{4S^2}{n} \quad \text{.....(2-2-2)}$$

Refer to the figure below for illustration.

Where n = Number of years of records.

When the points marked lie between the two control curves, the corresponding stations are considered homogenous.

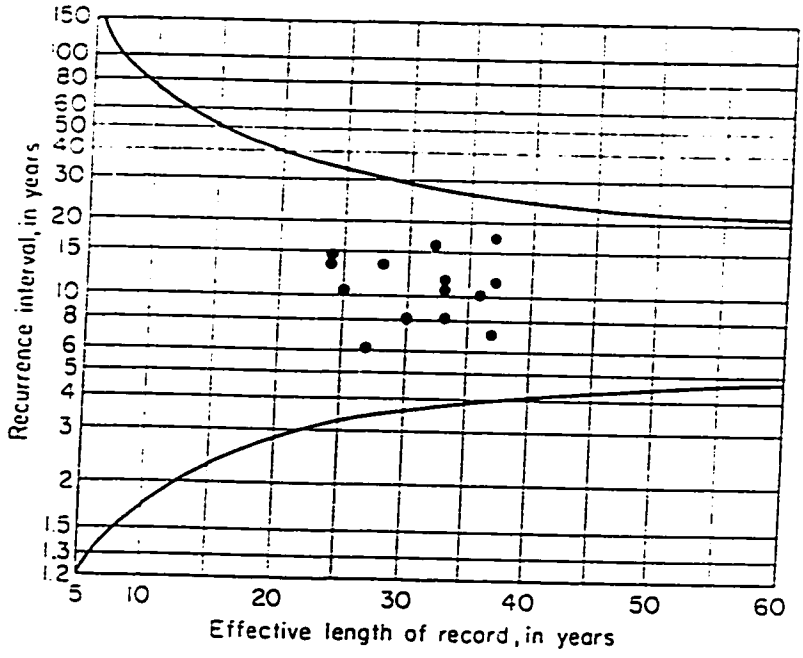


FIG 2 Homogeneity test graph. (*U.S. Geological Survey.*)

2.3 Gumbel Method "Extreme-Value Distribution"

Extreme value has mostly been used in flood frequency studies and it can be applied at the same time for rainfall analysis. The basic theory behind the extreme values method can be summarized as if X_1, X_2, X_3, - X_n are the extreme value for M sample having N number of events. and if X is an unlimited exponentially distributed variable, then the theory of extreme values states that, as M and N approach infinity, the cumulative probability P that any of M extremes will be less than X tends assymptotically to P where

$$P = Exp^{-Exp^{-y}} \quad \text{.....(2-3-1)}$$

y is the reduced variate

$$y = a\ (X - X_f) \quad \text{.....(2-3-2)}$$

X_f is the mode of distribution.

a is the distribution dispersion parameter.

μ_M and $\frac{1}{\alpha_M}$ are two parameters in the double exponential probability function. Where μ_M is the characteristic largest valve and α_M is an intensity function, μ_M increases as the logarithm of M, α_M may decrease with M and both α_M and $\frac{1}{\alpha_M}$ depend on the initial distribution.

For example :

1. Exponential distribution

$$\mu_M = \ln (M), \quad \alpha_M = 1 \quad \text{..... .(2-3-3)}$$

2. Logistic distribution

$$\mu_M = \ln(M-1);\ \alpha_M = 1 - \frac{1}{M} \quad \text{.....(2-3-4)}$$

Then the standard deviation of the largest value is

$$\sigma_M = \frac{\pi}{\sqrt{6}}\ \alpha_M \quad \text{.....(2-3-5)}$$

When N is large and the initial distribution is considered to be of exponential type, when M values are plotted using the frequency $\frac{N}{M+1}$ the plot should be scattered about the straight line, on the extreme probability paper.

$$x = \mu + {}^{y}/_{\alpha} \qquad (2\text{-}3\text{-}6)$$

When N is not large and we want to fit a straight line to N plotted on extreme value probability paper we modify equation 2-3-6 as follows :

$${}^{1}/_{\hat{\alpha}} = \frac{\sigma_x}{\sigma_N};\ \hat{\mu} = \bar{x} - \frac{\bar{y}_N}{\hat{\sigma}_x} \qquad (2\text{-}3\text{-}7)$$

Where σ_N and $\bar{y}_N$ are functions of N (Table 1). Then the straight line drawn on extreme value probability paper is

$$x = \bar{x} + \sigma_x \left(\frac{y - \bar{y}_N}{\sigma_N} \right) \qquad (2\text{-}3\text{-}8)$$

Equation 2-3-8 is the equation to fit a straight line to observed data for all values of N.

TABLE 1

MEANS AND STANDARD DEVIATIONS OF REDUCED EXTREMES

N	$\bar{y}_N$	σ_N	N	$\bar{y}_N$	σ_N
8	.4843	.9043	49	.5481	1.1590
9	.4902	.9288	50	.54854	1.16066
10	.4952	.9497	51	.5489	1.1623
11	.4996	.9676	52	.5493	1.1638
12	.5035	.9833	53	.5497	1.1653
13	.5070	.9972	54	.5501	1.1667
14	.5100	1.0095	55	.5504	1.1681
15	.5128	1.02057	56	.5508	1.1696
16	.5157	1.0316	57	.5511	1.1708
17	.5181	1.0411	58	.5515	1.1721
18	.5202	1.0493	59	.5518	1.1734
19	.5220	1.0566	60	.55208	1.17467
20	.52355	1.06283	62	.5527	1.1770
21	.5252	1.0696	64	.5533	1.1793
22	.5268	1.0754	66	.5538	1.1814
23	.5283	1.0811	68	.5543	1.1834
24	.5296	1.0864	70	.55477	1.18536
25	.53086	1.09145	72	.5552	1.1873
26	.5320	1.0961	74	.5557	1.1890
27	.5332	1.1004	76	.5561	1.1906
28	.5343	1.1047	78	.5565	1.1923
29	.5353	1.1086	80	.55688	1.19382
30	.53622	1.11238	82	.5572	1.1953
31	.5371	1.1159	84	.5576	1.1967
32	.5380	1.1193	86	.5580	1.1980
33	.5388	1.1226	88	.5583	1.1994
34	.5396	1.1255	90	.55860	1.20073
35	.54034	1.12847	92	.5589	1.2020
36	.5410	1.1313	94	.5592	1.2032
37	.5418	1.1339	96	.5595	1.2044
38	.5424	1.1363	98	.5598	1.2055
39	.5430	1.1388	100	.56002	1.20649
40	.54362	1.14132	150	.56461	1.22534
41	.5442	1.1436	200	.56715	1.23598
42	.5448	1.1458	250	.56878	1.24292
43	.5453	1.1480	300	.56993	1.24786
44	.5458	1.1499	400	.57144	1.25450
45	.54630	1.15185	500	.57240	1.25880
46	.5468	1.1538	750	.57377	1.26506
47	.5473	1.1557	1000	.57450	1.26851
48	.5477	1.1574			

From Gumbel (1958) p. 228.

2.4 General relationship Between Rainfall Values :

There are different relationships between rainfall frequency data which could be good tools in minimizing the effect of sampling deficiencies. **Hershfield** (3) and **Reich** (5) proposed valuable relationships for estimating short - duration rainfalls which provide basis for extrapolating from low return periods (≤2 years) to high return periods (50 or 100 years). There are two types of estimates in general (3) : estimation of rainfall depth when duration and return period are given; and estimation of return period when rainfall depth and duration are given .

2.5 Depth - duration Ratios. :

Hershfield (3) recommended an empirical relation from short-duration rainfalls to estimate depth - duration ratios for the United States. The relationship suggests that the rainfall depth has a consistent ratio to the 1-hr. rainfall depth of the same return period. These ratios are 0.79, 0.57, 0.45, and 0.29 for 30, 15, 10, 5 min. respectively (3) . **Bell** (4) made the ratio for 2 hours about 1.25 using 157 stations and more than 40 years of records. The average errors for these estimate are 5 - 8 % which is about the same value of deficiency error due to sampling . **Reich** (5) proposed that the U.S depth - duration ratios may be suitable for the whole world . He found similar values for South Africa . His study was completed in 1959 at the Iowa State University using fifteen stations covering the whole area of the country with an average length of record of 15 years.

Another study was done in Australia using more than 30 years of data and seven rainfall stations distributed throughout the country

The Australian ratios are 0.30 , 0.57 , 0.78 , and 1.24 for 5,15,30 and 120 min. respectively which is very close to that of USA.

One more study was done in U.S.S.R and this gave results similar to those for the USA.

2.6 Depth - frequency Ratios :

The mean ratios to the 10-years value were calculated for U.S.(4) for return periods of 1 , 2 , 5 , 25 , 50 , and 100 years. Those ratios are 0.54 , 0.63 , 0.85 , 1.17 , 1.31 , and 1.46 respectively.

Further studies were done for South Africa , Australia and other countries (4). Their ratios were obtained and found to be close to those of USA. For example the Australian ratios are: 0.52,0.65, 0.85,1.18, 1.33. and 1.50 for return periods of 1,2,5,25,50, and 100 years

2.7 Frequency - distribution of the Ratios :

The evaluation of depth - frequency ratios according to **Bell** (4) was achieved by plotting the mean ratios on **Gumbel** paper or semi-log paper, where they formed a straight line and the resulting frequency distribution was given as follows :

$$\frac{P_T^t}{P_{10}^t} = 0.21 \ln T + 0.52 \quad \text{if } 2 \leq T \leq 100 \text{ years} \qquad \text{.....(2-7-1)}$$

Where P_T^t is the depth of "t - min., T - years" return period rainfall and P_{10}^t is the depth of "t - min. 10 - years" return period rainfall.

Gumbel distribution can be used for extrapolation to higher values if needed.

2.8 Generalized Depth - duration -frequency Relationships :

When the depth - duration ratios are combined with depth - frequency ratios a generalized depth - duration - frequency relationship can be given as shown below (4) :

First we express the depth - duration ratios as follows :

$$\frac{P_T^t}{P_T^{60}} = 0.54\ t^{0.25} - 0.50 \text{ if } 5 \leq t \leq 120 \text{ min} \quad \text{.....(2-8-1)}$$

Where P_T^{60} is the depth of rainfall for duration of 60 min. for any return periods.

If Equ. (3) and (4) are combined we can form the generalized depth - duration - frequency relationship as :

$$P_T^t = (0.21 \ln T + 0.52)\left(0.54\ t^{0.25} - 0.5\right) P_{10}^{60} \quad \text{.....(2-8-2)}$$

The last equation given is useful in estimating the rainfall depth for any duration from 5 to 120 min. and any return period from 2 years to 100 years.

2.9 Other IDF Relation :

One study was done in Canada to confirm the independence of short-duration rainfall depth-duration relationships from geographical factors (9). A rainfall intensity equation was obtained using least squares technique.

$$R(t,T) = A_T \; t^{B_T} \quad \text{.....(2-9-1)}$$

Where R=Rainfall rate in mm/hr for duration t in minutes and return period T in years. A_T and B_T are the regression constants.

Another relation was obtained for calculating the rainfall depth as follows:

$$h_{t,T} = \left(\frac{A_T}{60}\right) t^{(1+B_T)} \quad \text{.....(2-9-2)}$$

where $h_{t,T}$ = the rainfall depth in a period of t min. and T return period.

The third relation of time for Canada is the ratio of the depth of rainfall for duration less than 1 hour to the amount of 1 hour which the author suggested it constant for all return periods.

$$\frac{h_t}{h_{60}} = \frac{(1)}{60^{(1+B_T)}} t^{(1+B_T)} \quad \text{.....(2-9-3)}$$

The conclusion of that study was that the depth-duration relationship in Canada is dependent of geography.

Chapter 3

METHODS AND MATERIALS

3.1 General:

In this study the objective is to predict short - duration , high - intensity rainfall for Saudi Arabia, and then compare it with the relations of other countries such as U.S.A., Australia and South Africa.

In addition to that, mathematical models for each region in Saudi Arabia were developed. The analysis contains 28 stations covering the 9 operational regions in the **Kingdom .**

3.2 Procedure and Sample Calculations :

Rainfall data for 28 stations in Saudi Arabia were obtained from "**Hydrological Publications**" ; **Ministry of Agriculture & Water** , according to availability of data (having at least 10 years of records). **Table 2** shows the number of stations for each region.

I	2
II	4
III	4
IV	3
V	3
VI	4
VIII	3
IX(JMT)	5

Table 2

Then the data collected were analysed using the computer program **Gumbel 2** which assumes extreme value distribution of data. The output is shown in **Appendix A** which provides intensity - duration data. Having got the intensity - duration data ; intensity - duration curves were plotted on **Gumbel** papers as shown in **Appendix B.** Then analysis was started.

3.3 For verification of **Hershfield's** relations, the tables in **Appendix C** are produced by taking the ratios of $\frac{P^t}{P^{60}}$

where t = duration in min., P^t is the depth of rainfall at time t, and

P_T^{60} is the depth of rainfall at t = 60 min. for return periods of T= 50,25,10,5 and 2 years .

Example

Tabuk Station

At T = 50 years

t = 10 min.

$$\frac{P^{10}}{P^{60}} = \frac{74.41}{6 \times 16.23} = 0.764$$

3.4 For verifications of **Bell's** ratios of depth-frequency-relationships as shown in **Table 3,**

The $\frac{P_T^t}{P_{10}^t}$ are calculated for

T = 50,25,10,5, and 2 years

and for t = 60 min.

Example :

Tabuk Station

T = 50 years

t = 60 min.

$$\frac{P_{50}^{60}}{P_{10}^{60}} = \frac{16.23}{11.16} = 1.454$$

3.5 For verifications of **Bell's** ratios when the depth-frequency relationship was combined with depth as shown in **Table 4**,

$\frac{P_T^t}{P_T^{60}}$ ratios were calculated

For T = 25 years

and t = 10,30, and 120 min.

Example :

Tabuk Station

T = 25 years

t= 10 min

$$\frac{P_{25}^{10}}{P_{25}^{60}} = \frac{63.27}{6x14.07} = 0.749$$

The values were verified and was not positive. So there was a need to find a model for each region in Saudi Arabia. Then, the average values for each area were calculated , and in addition the average rainfalls for each area were calculated and analysed using **Gumbel 2** program. The result is shown in **Appendix F**.

Next, average values were obtained from the coefficients in **Appendix D** and **Appendix E** (model curves), from the intensities in **Tables 7** and **8**, and from the average rainfalls as in **Appendix F**

The average values for the relations calculated above are tabulated in **Tables 5** and **6** in the result and discussion part in the next chapter.

Bell proposed an empirical relation for high-intensity, short-duration rainfall depths, as follows :

$$\frac{P_T^t}{P_{10}^t} = 0.21 \ln T + 0.52, \; 2 \le T \le 100 \text{ years}$$

Where P = The depth of rain in mm.
T = Return period in years.
t = Duration in min.

The values of (0.21 ln T + 0.52) are presented in the table below for 28 stations in Saudi Arabia.

For duration, t = 60 min.

Ratios of Saudi Arabia using Bell's depth - frequency relations.

AREA	STATION NAME	RETURN PERIOD, T - YEARS							
		50	%Diff.	25	%Diff.	5	%Diff.	2	%Diff.
I	TABUK	1.454	8.0	1.261	5.4	0.794	7.4	0.482	27.6
	SAKKAKAH	1.517	13.0	1.296	8.4	0.765	10.8	0.410	38.40
II	SULAYYIL	1.50	11.8	1.287	7.6	0.773	9.9	0.430	35.4
	NAJRAN	1.477	10.0	1.274	6.5	0.783	7.4	0.456	31.5
	AL AIN QATAN	1.574	17.3	1.33	11.2	0.739	13.9	0.345	48.2
	THAWILA POLICE P.	1.425	6.2	1.244	4.0	0.807	5.9	0.515	22.6
III	SERAT ABIDA	1.448	7.9	1.406	17.6	0.890	3.8	0.546	18.0
	ABU JINNAHA	1.574	17.3	1.33	11.2	0.739	13.9	0.345	48.2
	BISHAH	1.66	23.7	1.379	15.30	0.700	18.40	0.46	30.1
	AINNIMAS	1.371	2.0	1.218	1.44	0.831	2.6	0.576	13.5
IV	YABRIN	1.461	8.9	1.265	5.7	0.791	7.9	0.474	28.8
	HARDAH	1.453	8.27	1.260	5.4	0.794	7.4	0.483	27.5
	AL SARRAR	1.39	3.5	1.224	2.3	0.823	4.1	0.555	16.7
V	KHURA'S	1.498	11.6	1.286	7.5	0.774	9.8	0.432	35.0
	AL KHARJ	1.533	14.1	1.376	15.1	0.758	11.7	0.393	41.0
	RIYADAH	1.472	9.7	1.27	6.2	0.785	8.5	0.461	30.8
VI	SUWAYDRAH	1.531	14.1	1.305	9.11	0.758	11.6	0.394	40.8
	AL MEDINA FARM	1.514	12.8	1.296	8.4	0.766	10.7	0.413	37.9
	KWASH	1.330	0.92	1.189	0.56	0.850	0.91	0.624	6.3
	KHUBAH	1.420	5.6	1.24	3.7	0.810	5.6	0.523	21.5
VIII	KIYAT	1.555	15.9	1.319	10.2	0.748	12.8	0.367	44.9
	HANAKIYAH	1.629	21.4	1.369	14.5	0.740	13.8	0.320	52.0
	MURAYR	1.544	15.0	1.312	9.7	0.753	12.2	0.380	42.9
IX	TAIF	1.397	4.1	1.228	2.6	0.820	4.5	0.547	17.9
	JERMUZ	1.427	6.3	1.245	4.1	0.806	6.0	0.513	23.0
	HEMA SAYSID	1.434	6.8	1.249	4.4	0.803	6.4	0.505	24.2
	WADI DAHIYAH	1.332	0.7	1.190	0.5	0.849	1.0	0.621	6.7
	AIN AZIZIZYAH	1.544	15.0	1.312	9.7	0.753	12.2	0.379	43.1
$\frac{P_T^t}{P_{10}^t}$ = 0.21 ln T + 0.52		1.342		1.196		0.858		0.666	

Table 3

Bell proposed an empirical relation for high-intensity, short-duration rainfall depths, as follows :

$$\frac{P_T^t}{P_T^{60}} = 0.54\ t^{.25} - 0.5,\quad 5 \le t \le 120 \text{ min.}$$

Where P = The depth of rain.
T = Return period in years.
t = Duration in min.

The values of $\left(0.54\ t^{.25} - 0.5 \right)$ are presented in the table below for 28 stations in Saudi Arabia.

For Return period, T = 25 years :

Ratios of Saudi Arabia using Bell's depth - duration relations.

AREA	NAME	10 min.	%Diff.	30 min.	%Diff.	120 min.	%Diff.
I	TABUK	0.749	62.8	0.855	12.1	1.402	8.9
	SAKKAKAH	0.622	35.2	0.659	13.6	1.226	4.7
II	SULAYYIL	0.572	24	0.81	6.2	1.167	9.3
	NAJRAN	0.478	3.9	0.882	15.6	1.009	21.6
	AL AIN QATAN	0.359	21.9	0.93	21.9	1.154	10.3
	THAWILA POLICE POST	0.508	10.4	0.919	21.4	1.083	15.8
III	SERAT ABIDA	0.478	3.9	0.787	3.1	1.392	8.2
	ABU JINNAHA	0.295	35.8	0.741	2.9	1.378	7.1
	BISHAH	0.517	12.4	0.868	13.8	1.052	18
	AINNIMAS	0.528	14.8	0.857	12.3	1.099	14.6
IV	YABRIN	0.681	48	0.878	15.1	1.134	11.9
	HARDAH	0.456	0.9	0.83	8.8	1.123	12.7
	AL SARRAR	0.726	57.8	0.786	3.0	1.21	6.0
V	KHURA'S	0.501	8.9	0.777	1.8	1.016	21.0
	AL KHARJ	0.611	32.8	0.843	10.5	1.249	3.0
	RIYADAH	0.56	21.2	0.809	6.0	1.112	13.6
VI	SUWAYDRAH	0.503	9.3	0.909	25	1.104	14.2
	AL MEDINA FARM	0.575	25	0.794	4.1	1.197	7.0
	KWASH	0.612	33	0.752	1.4	1.032	19.8
	KHUBAH	0.417	9.3	0.79	3.5	1.058	17.9
VIII	KIYAT	0.351	23.7	0.706	7.5	1.154	10.3
	HANAKIYAH	0.492	7.0	0.86	12.7	1.185	7.9
	MURAYR	0.713	35	0.91	25	1.105	14.1
IX	TAIF	0.45	2.2	0.796	4.3	1.079	16.1
	JERMUZ	0.441	4.1	0.763	0.0	1.241	3.6
	HEMA SAYSID	0.39	15.1	0.761	0.3	1.071	16.8
	WADI DAHIYAH	0.352	23.5	0.758	0.7	1.144	11.1
	AIN AZIZIYAH	0.348	24	0.646	15.3	1.286	0.1
$\frac{P_T^t}{P_T^{60}} = 0.54\ t^{0.25} - 0.5$		0.46		0.763		1.287	

Table 4

Chapter 4

RESULTS AND DISCUSSION

From the results in **Appendix C, Appendix D** and **Appendix E** we notice that the ratios obtained are not close to those obtained by **Hershfield** and not within the limit given by **Bell (5-8%)** in most of the stations in Saudi Arabia. The reason for the variations in the ratios is due to the difference in the producing mechanisms of short-duration rainfall between the two countries. According to the topographical features of Saudi Arabia (7) the dominant climate is arid except for the Asir region in the southwest of the kingdom. The aridity occurs from the climate and from the physical aspects which include circulation of air , location of moisture sources , and the mountains in the west which act as barriers. "The winds and air currents reaching Arabia have already lost most of their moisture over African and Eurasian land masses and can partly replenish their moisture content from the narrow bodies of water that bound the peninsula" (8). In general, rainfall in the kingdom is light, irregular, cannot be predicted , and differs from region to region . Asir is an exception , where it gets a high depth of rainfall (20 inches). "The mountains bounding this coastal area force the westerly winds upward, causing the release of enough moisture to provide Asir with an estimated 10 to 20 inches annual precipitation" (8) . The producing mechanism of short-duration high-intensity rainfall in Saudi Arabia depends mostly on thunderstorm which is caused by severe convective storms. Convective storms occur when air at ground level is heated and expands, rising vertically, then getting colder, condensing and thus causing the formation of droplets which

then come down as rainfall. Thunderstorms occur due to the rising of clouds vertically at an average of height of 30,000 ft and average wind speed of 50 mph (9). The South west of the Kingdom gets its rain from an orographic phenomenon, produced by lifting of moist air masses over mountains (9). Thus it is important that mathematical models for each region in the kingdom be formulated.

Three methods have been used in this paper :

1- By averaging the coefficients for each region from the models **(Appendices D and E)** as shown in **Table 5** and **Table 6**

2- By averaging the rainfall data from **Appendix A** and tabulating it in **Appendix F** as shown in **Appendix G** and **Appendix H.**

3- By averaging the intensities for each region from **Tables 3 & 4** as shown in **Appendix I** and **Appendix K,** and also in **Table 5** and **Table 6.**

The average values (average models) tabulated in **Tables 5** and **6** are verified for each region and the results are tabulated in **Tables 7** and **8.**

Summary of Models (Average Values) for Each Region

1. The Average Values of Models for depth - frequency - relationship : $\frac{P_T^t}{P_{10}^t}$

Area	Average Coefficients	Average Intensities	Average Rainfalls
I	0.3152 ln (X) + 0.2548	0.3261 ln (X) + 0.2361	0.2727 ln (X) + 0.3565
II	0.3214 ln (X) + 0.2407	0.3214 ln (X) + 0.2408	0.2897 ln (X) + 0.3192
III	0.319225 ln (X) + 0.27195	0.3192 ln (X) + 0.2714	0.2588 ln (X) + 0.3879
IV	0.2794 ln (X) + 0.3379	0.2792 ln (X) + 0.3383	0.2382 ln (X) + 0.4363
V	0.32457 ln (X) + 0.2353	0.3251 ln (X) + 0.2344	0.2338 ln (X) + 0.448
VI	0.28957 ln (X) + 0.4083	0.2894 ln (X) + 0.3152	0.2418 ln (X) + 0.429
VIII	0.367 ln (X) + 0.1361	0.3666 ln (X) + 0.1363	0.2849 ln (X) + 0.3275
IX (JMT)	0.27468 ln (X) + 0.3493	0.2743 ln (X) + 0.3476	0.2218 ln (X) + 0.4723

Where X is Return Period, T-years

Table 5

2. The Average values of models when the depth-frequency relationship was combined with depth - duration data : $\frac{P_T^t}{P_T^{60}}$

Area	Average Coefficients	Average Intensities	Average Rainfalls
I	$0.3491\ X^{0.26475}$	$0.3482\ X^{0.2631}$	$0.7694\ X^{0.0599}$
II	$0.24655\ X^{0.3407}$	$0.2431\ X^{0.3357}$	$0.2875\ X^{0.2952}$
III	$0.20745\ X^{0.407475}$	$0.1935\ X^{0.3904}$	$0.2712\ X^{0.3065}$
IV	$0.35527\ X^{0.2604}$	$0.3498\ X^{0.2526}$	$0.2329\ X^{0.35}$
V	$0.29473\ X^{0.28883}$	$0.2943\ X^{0.289}$	$0.1978\ X^{0.4399}$
VI	$0.274525\ X^{0.30777}$	$0.2747\ X^{0.3024}$	$0.1681\ X^{0.4051}$
VIII	$0.28013\ X^{0.3395}$	$0.2584\ X^{0.3224}$	$0.1906\ X^{0.3908}$
IX (JMT)	$0.156\ X^{0.44388}$	$0.1525\ X^{0.4424}$	$0.1784\ X^{0.4018}$

Where X is duration, t-min.

Table 6

Verification of Ratio for Average Models

1. Ratios of depth - frequency - relationship, for return period, T = 10 years : $\frac{P_{10}^{t}}{P_{10}^{t}} = 1.0$

	RATIOS					
Area	**Average Coefficients**	**% dif**	**Average Intensities**	**% dif**	**Average Rainfalls**	**% dif**
I	0.9805	1.9	0.987	1.3	0.9877	1.6
II	0.9807	1.9	0.9809	1.9	0.9863	1.3
III	1.007	0.7	1.006	0.6	0.9838	1.6
IV	0.9812	1.9	0.9812	1.9	0.9848	1.5
V	0.9827	1.7	0.9830	1.7	0.9863	1.6
VI	1.075	7.5	0.9816	1.8	0.9858	1.4
VIII	0.9811	1.9	0.9804	2.0	0.9835	1.6
IX (JMT)	0.98177	1.8	0.9792	2.6	0.9830	1.7

Table 7

2. Ratios when the depth-frequency relationship was combined with depth-duration data for duration, t = 60 min : $\frac{P_{T}^{60}}{P_{T}^{60}} = 1.0$

	RATIOS					
Area	**Average Coefficients**	**% dif**	**Average Intensities**	**% dif**	**Average Rainfalls**	**% dif**
I	1.032	3.2	1.022	2.2	0.98	2
II	0.9948	0.5	0.961	3.9	0.963	3.7
III	1.1	10	0.956	4.4	0.951	4.9
IV	1.032	3.2	0.984	1.6	0.976	2.4
V	0.962	3.8	0.961	3.9	1.198	19.8
VI	0.968	3.2	0.947	5.3	0.882	11.8
VIII	1.12	12	0.967	3.3	0.944	5.6
IX (JMT)	0.96	4	0.933	4.7	0.924	7.6

Table 8

From the verification **Tables 7** and **8**, we conclude that the average rainfalls (**Table 7**) have the least % diff. among the average coefficients and the average intensities while the average intensities (**Table 8**) have the least % diff. among the average rainfall data and the average coefficients, so they can be chosen as relations for Saudi Arabia as shown in the Table below.

SUMMARY OF THE RESULTS

(1) Area	(2) Depth - Frequency - Relationship, $\frac{P_T}{P_{10}^{60}}$	(3) Depth - Duration - Relationship, $\frac{P_T^t}{P_T^{60}}$	(4) Depth - Frequency - Relationship when depth - frequency was combined with depth - duration, P_T
I	0.2727 ln T + 0.3565	0.3482 $t^{0.2631}$	(0.2727 ln T + 0.3565) (0.3482 $t^{0.2631}$) P_{10}^{60}
II	0.2897 ln T + 0.3192	0.2431 $t^{0.3357}$	(0.2897 ln T + 0.3192) (0.2431 $t^{0.3357}$) P_{10}^{60}
III	0.2588 ln T + 0.3879	0.1935 $t^{0.3904}$	(0.2588 ln T + 0.3879) (0.1935 $t^{0.3904}$) P_{10}^{60}
IV	0.2382 ln T + 0.4363	0.3498 $t^{0.2526}$	(0.2382 ln T + 0.4363) (0.3498 $t^{0.2526}$) P_{10}^{60}
V	0.2338 ln T + 0.448	0.2943 $t^{0.289}$	(0.2338 ln T + 0.448) (0.2943 $t^{0.289}$) P_{10}^{60}
VI	0.2418 ln T + 0.429	0.2747 $t^{0.3024}$	(0.2418 ln T + 0.429) (0.2747 $t^{0.3024}$) P_{10}^{60}
VIII	0.2849 ln T + 0.3275	0.2584 $t^{0.3224}$	(0.2849 ln T + 0.3275) (0.2584 $t^{0.3224}$) P_{10}^{60}
IX (JMT)	0.2218 ln T + 0.4723	0.1525 $t^{0.4424}$	(0.2218 ln T + 0.4723) (0.1525 $t^{0.4424}$) P_{10}^{60}

Table 9

The combined relations in column (4) in the table above are very useful models in estimating rainfall depth for any duration from 5 min. to 120 min. and any return periods from 2 to 100 years for any region in Saudi Arabia.

Chapter 5

CONCLUSION

The paper presents some insight into the way in which the rainfall is produced in the kingdom of Saudi Arabia. This is different from that of other countries such as USA, Australia & South Africa. Thus, the formulas of **Hershfield** and **Bell** are not applicable in the kingdom. Hence it is important to find specific relations for the kingdom. Since the kingdom is large and has different climatic conditions from region to region , a mathematical model (relation) for each region has been obtained to act as a useful tool in estimating rainfall depth for short durations($5 \leq t \leq 120$ min.) and return periods of $2 \leq T \leq 100$ years.

APPENDICES

APPENDIX A

A_1 - A_{28}

RAINFALL DATA & INTENSITY / DURATION DATA TABLES

Rainfall Depth (mm)

A1

Station: Tabuk **Region:** I

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.50700

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.99720

S. NO.	Duration (min.)			
	10	30	60	120
1	0.90	0.90	0.90	0.90
2	1.00	3.00	4.10	9.80
3	3.00	5.00	5.00	9.50
4	2.50	3.80	4.20	6.00
5	6.00	7.50	7.50	7.50
6	1.50	4.50	6.50	6.50
7	1.40	3.40	5.60	5.60
8	2.00	3.40	3.40	3.40
9	3.80	6.20	6.60	6.60
10	4.00	4.00	4.00	4.00
11	9.60	10.00	11.20	19.00
12	2.00	4.20	4.60	4.60
13	7.00	9.40	12.00	12.20

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	84.00	31.00	18.00	13.50
50	74.41	27.77	16.23	11.48
25	63.27	24.10	14.07	9.86
10	48.25	19.15	11.16	7.68
5	36.36	15.23	8.86	5.96
2	18.41	9.31	5.38	3.35

Rainfall Depth (mm)

A2

Station: Sakkakah **Region:** I

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.50700

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.99720

S. NO.	Duration (min.)			
	10	30	60	120
1	0.00	0.00	2.50	2.70
2	0.00	0.00	4.50	5.00
3	0.00	0.00	10.00	10.80
4	0.00	0.00	11.50	20.30
5	0.00	0.00	24.80	28.90
6	0.00	0.00	7.40	8.40
7	0.70	1.10	1.30	1.30
8	5.20	7.00	7.00	7.00
9	9.50	9.80	9.80	12.00
10	8.00	10.80	10.80	10.80
11	12.30	12.80	12.80	13.30
12	1.70	3.50	3.50	3.50
13	7.80	8.00	8.00	8.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	131.00	47.00	34.00	20.00
50	112.14	40.55	29.24	17.99
25	93.23	33.78	24.99	15.32
10	67.74	24.66	19.28	11.71
5	47.56	17.43	14.75	8.85
2	17.08	6.52	7.91	4.54

Rainfall Depth (mm)

A3

Station: Sulayyil **Region:** II

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49960

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.96760

S. NO.	Duration (min.)			
	10	30	60	120
1	1.50	2.00	2.70	2.70
2	3.00	16.00	16.00	16.00
3	5.70	6.00	6.20	6.20
4	5.00	5.50	7.50	10.30
5	8.50	17.00	17.00	22.00
6	8.00	10.00	10.50	10.50
7	16.50	21.00	26.50	32.50
8	6.00	6.00	9.20	9.20
9	7.00	9.60	10.00	10.00
10	12.00	12.00	22.00	22.00
11	4.40	4.40	4.60	4.60

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	150.00	70.00	44.00	25.00
50	131.38	61.97	38.34	22.46
25	112.97	53.28	32.90	19.19
10	88.15	41.55	25.56	14.78
5	68.51	32.28	19.76	11.29
2	38.84	18.26	10.99	6.02

Rainfall Depth (mm)

A4

Station: Najran **Region: II**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.50350

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.98330

S. NO.	Duration (min.)			
	10	30	60	120
1	8.40	8.40	8.40	8.60
2	10.00	22.20	28.20	28.40
3	5.20	8.40	8.40	8.40
4	8.40	8.40	8.60	9.40
5	4.40	6.00	8.40	8.60
6	15.00	25.60	26.40	26.40
7	5.40	12.80	15.20	15.60
8	4.20	6.00	6.00	12.00
9	9.40	15.40	16.80	18.80
10	7.30	10.60	11.10	12.70
11	4.20	4.20	5.60	6.20
12	8.00	13.00	14.40	16.60

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	124.00	79.00	45.00	21.00
50	110.26	68.93	39.11	19.59
25	96.74	59.53	33.73	17.02
10	78.52	46.85	26.48	13.55
5	64.10	36.82	20.74	10.80
2	42.32	21.67	12.08	6.65

Rainfall Depth (mm)

A5

Station: Tabuk **Region:** II

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.50350

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.98330

S. NO.	Duration (min.)			
	10	30	60	120
1	0.40	0.80	1.00	1.00
2	5.00	6.80	8.60	12.80
3	11.40	12.20	12.20	12.20
4	2.40	4.80	4.80	4.80
5	4.40	5.80	9.60	12.40
6	7.20	13.80	13.80	13.80
7	1.60	1.60	1.60	1.60
8	8.20	11.40	13.00	16.00
9	12.60	21.00	24.40	25.40
10	12.00	23.80	24.00	25.00
11	0.40	0.40	0.40	0.40
12	1.40	1.80	1.80	2.60

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	147.00	82.00	44.00	23.00
50	128.87	71.77	38.51	20.53
25	109.13	60.51	32.53	17.39
10	82.52	45.33	24.46	13.15
5	61.46	33.32	18.08	9.79
2	29.66	15.17	8.43	4.72

Rainfall Depth (mm)

A6

Station: Thawila **Region:** II

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.50350

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.98330

S. NO.	Duration (min.)			
	10	30	60	120
1	5.60	7.40	8.60	15.80
2	10.00	18.20	24.40	30.00
3	9.60	11.40	14.00	14.00
4	9.60	9.60	9.80	10.00
5	2.40	4.20	4.20	5.20
6	11.00	17.20	17.20	17.20
7	3.60	6.20	10.10	14.20
8	7.80	17.80	24.40	27.80
9	11.00	22.60	22.60	26.20
10	15.00	29.40	30.20	30.20
11	9.00	17.00	18.60	21.40
12	14.00	18.00	18.60	19.20

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	148.00	90.00	49.27	27.00
50	132.50	80.67	43.72	23.55
25	116.31	70.15	38.17	20.67
10	94.49	55.96	30.68	16.79
5	77.23	44.74	24.76	13.71
2	51.15	27.78	15.81	9.07

Rainfall Depth (mm)

A7

Station: Serat Abida **Region:** III

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.53320

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 1.10040

S. NO.	Duration (min.)			
	10	30	60	120
1	3.20	6.40	7.20	7.20
2	5.20	7.20	10.60	13.00
3	17.00	30.00	34.60	34.80
4	11.20	25.00	27.00	29.20
5	11.40	21.30	35.70	61.70
6	11.80	16.00	20.40	23.10
7	10.40	13.40	17.80	23.40
8	11.00	17.00	18.50	23.00
9	13.00	19.60	25.80	26.60
10	2.00	2.60	4.00	5.20
11	6.80	12.20	15.80	17.00
12	4.60	11.80	12.40	20.80
13	2.80	5.60	5.80	5.80
14	5.60	7.00	7.00	7.00
15	10.00	17.00	17.00	17.00
16	9.00	17.00	23.20	43.00
17	6.00	11.60	19.00	28.00
18	14.20	14.20	17.00	19.00
19	9.40	15.80	17.60	18.20
20	5.20	8.40	9.80	12.60
21	6.80	12.00	16.20	16.40
22	6.80	8.80	8.80	8.80
23	4.00	5.60	5.60	5.60
24	2.60	7.20	8.20	8.20
25	6.60	6.60	6.60	6.60
26	9.40	11.20	11.20	11.20
27	4.00	5.60	9.00	10.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	133.00	75.00	47.00	34.00
50	118.13	64.92	41.41	29.17
25	103.21	56.56	35.95	25.02
10	83.09	45.30	28.59	19.43
5	67.17	36.38	22.76	15.00
2	43.13	22.92	13.96	8.32

Rainfall Depth (mm)

A8

Station: Abu Jinnaha **Region:** **III**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49520

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.94970

S. NO.	Duration (min.)			
	10	30	60	120
1	5.40	10.80	12.80	17.20
2	4.20	6.20	6.80	10.00
3	4.60	6.20	8.40	10.60
4	7.00	8.40	9.20	14.60
5	5.40	5.40	8.00	10.60
6	7.90	10.80	11.20	11.20
7	7.20	11.00	14.10	21.80
8	13.00	34.00	46.40	63.60
9	6.60	12.40	13.40	14.00
10	5.20	8.00	8.00	8.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	104.50	93.50	64.50	45.00
50	94.42	82.34	55.89	38.62
25	83.16	70.01	47.21	32.52
10	67.99	53.40	35.50	24.30
5	55.98	40.25	26.23	17.79
2	37.84	20.38	12.24	7.96

Rainfall Depth (mm)

A9

Station: Bishah **Region:** III

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.50700

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.99720

S. NO.	Duration (min.)			
	10	30	60	120
1	1.00	15.20	15.20	15.20
2	1.00	4.60	4.60	4.60
3	1.50	8.80	8.80	8.80
4	1.00	7.20	7.20	9.20
5	7.00	8.20	8.20	14.00
6	4.50	4.80	5.80	5.80
7	16.30	29.50	31.00	31.00
8	33.00	33.00	39.00	39.00
9	10.50	10.50	10.50	12.50
10	41.00	82.00	95.00	101.00
11	10.00	11.30	11.30	11.30
12	2.40	3.00	3.20	3.20
13	4.40	5.80	8.60	8.60

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	337.00	209.00	121.00	65.00
50	323.56	181.26	104.59	55.00
25	269.29	150.84	86.88	45.71
10	196.15	109.84	63.00	33.19
5	138.26	77.39	44.11	23.28
2	50.82	28.37	15.57	8.31

Rainfall Depth (mm)

A10

Station: Ain Nimas **Region:** III

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49960

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.96760

S. NO.	Duration (min.)			
	10	30	60	120
1	7.60	7.90	7.90	7.90
2	15.00	36.50	36.50	36.50
3	10.00	32.60	32.60	35.20
4	9.00	17.40	17.40	25.00
5	16.00	32.60	32.60	39.00
6	25.22	31.40	31.40	40.20
7	24.00	42.80	42.80	45.00
8	15.00	42.20	42.20	42.20
9	11.50	30.30	30.30	37.50
10	11.00	30.40	30.40	40.00
11	6.00	19.80	19.80	21.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	242.00	127.00	74.20	40.00
50	213.97	114.43	66.63	36.43
25	186.69	101.01	58.94	32.38
10	149.90	82.91	48.58	26.92
5	120.79	68.58	40.38	22.60
2	76.82	46.95	27.99	16.07

Rainfall Depth (mm)

A11

Station: Yabrin **Region:** IV

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49960

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.96760

S. NO.	Duration (min.)			
	10	30	60	120
1	2.40	4.00	4.00	4.80
2	1.40	2.20	3.20	4.00
3	6.60	13.20	16.40	18.40
4	6.00	6.60	8.80	12.20
5	3.80	4.60	6.20	11.60
6	2.60	3.80	6.80	9.20
7	3.00	4.20	5.00	5.80
8	1.80	3.20	5.60	7.00
9	10.60	11.80	11.80	11.80
10	2.20	4.60	4.60	6.00
11	7.80	9.00	10.00	10.20

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	101.00	43.00	24.00	14.00
50	88.72	37.86	21.42	12.05
25	75.81	32.56	18.54	10.51
10	58.41	25.42	14.66	8.43
5	44.65	19.76	11.59	6.79
2	23.85	11.21	6.95	4.30

Rainfall Depth (mm)

A12

Station: Haradah **Region:** **IV**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49520

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.94970

S. NO.	Duration (min.)			
	10	30	60	120
1	3.80	9.20	12.40	13.40
2	4.00	6.40	8.80	12.20
3	2.20	3.80	3.80	3.80
4	3.60	8.00	9.40	10.80
5	7.20	12.80	14.60	15.60
6	1.00	1.20	2.00	3.00
7	4.60	5.60	6.60	8.20
8	3.20	4.80	5.60	10.00
9	4.40	4.60	7.20	7.60
10	2.20	4.00	5.60	6.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	66.00	40.00	24.00	13.00
50	58.05	35.52	21.32	11.90
25	50.55	30.68	18.49	10.38
10	40.43	24.16	14.67	8.33
5	32.43	18.99	11.65	6.70
2	20.35	11.19	7.08	4.25

Rainfall Depth (mm)

A13

Station: Al Sarrar **Region:** **IV**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49960

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.96760

S. NO.	Duration (min.)			
	10	30	60	120
1	5.60	5.60	6.20	7.80
2	1.80	3.80	4.80	6.60
3	6.80	8.60	12.00	18.40
4	2.60	4.00	4.80	7.60
5	9.00	10.80	12.20	12.80
6	7.60	7.60	11.60	12.60
7	3.40	4.80	5.00	5.00
8	3.40	6.00	8.40	11.20
9	3.60	6.00	8.00	9.40
10	9.40	11.20	13.20	13.60
11	6.40	6.40	6.40	6.60

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	100.00	34.00	22.00	14.00
50	87.86	31.25	19.93	12.07
25	76.42	27.60	17.55	10.62
10	60.99	22.68	14.34	8.67
5	48.78	18.79	11.80	7.13
2	30.34	12.91	7.97	4.80

Rainfall Depth (mm)

A14

Station: Khurais **Region: V**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.50350

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.98330

S. NO.	Duration (min.)			
	10	30	60	120
1	3.20	7.00	8.40	8.60
2	7.00	12.20	13.40	13.40
3	11.40	16.00	20.40	20.80
4	3.00	5.20	6.40	10.00
5	4.20	4.60	4.60	7.40
6	8.40	15.20	21.20	21.20
7	4.70	4.70	6.00	6.00
8	8.40	10.60	11.60	14.00
9	5.60	8.20	9.40	9.60
10	1.80	1.80	2.40	2.60
11	2.80	3.20	3.20	3.80
12	3.40	6.00	10.20	11.80

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	105.00	55.00	35.00	17.00
50	92.18	47.86	30.92	15.59
25	79.71	41.22	26.54	13.48
10	62.91	32.27	20.64	10.63
5	49.61	25.19	15.97	8.38
2	29.52	14.49	8.91	4.97

Rainfall Depth (mm)

A15

Station: Al Kharj **Region:** **V**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49960

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.96760

S. NO.	Duration (min.)			
	10	30	60	120
1	0.80	1.40	2.50	2.70
2	10.00	13.30	13.40	13.60
3	6.70	6.70	6.70	12.50
4	1.50	2.00	3.00	6.20
5	6.00	6.50	6.70	6.70
6	2.00	7.00	9.20	14.40
7	8.00	14.00	19.60	22.20
8	3.60	3.80	3.80	4.20
9	2.00	3.00	3.80	4.40
10	8.00	10.50	10.50	10.50
11	1.40	2.60	3.00	5.20

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	110.00	51.00	30.00	18.00
50	96.42	44.30	26.32	16.39
25	82.13	37.81	22.42	14.00
10	62.86	29.05	17.17	10.77
5	47.60	22.11	13.01	8.21
2	24.57	11.64	6.74	4.35

Rainfall Depth (mm)

A16

Station: Riyadah **Region: V**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.52020

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 1.04930

S. NO.	Duration (min.)			
	10	30	60	120
1	1.00	10.00	10.00	11.50
2	3.50	9.00	11.50	13.50
3	4.00	12.00	20.00	20.50
4	1.00	1.00	2.00	3.00
5	4.00	7.00	10.00	13.00
6	7.00	11.00	14.50	17.00
7	4.50	4.50	5.00	5.80
8	2.00	2.20	2.80	4.00
9	14.00	18.60	21.00	25.00
10	4.00	10.00	13.50	13.60
11	1.00	2.20	3.50	4.00
12	1.00	2.00	3.80	4.80
13	5.50	6.00	9.00	9.00
14	5.00	5.00	5.60	10.80
15	10.00	11.80	11.80	11.80
16	6.60	10.40	11.80	14.20
17	4.70	5.20	6.80	8.00
18	5.20	5.60	5.60	6.80

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	105.00	50.00	31.00	17.00
50	92.55	44.19	27.27	15.09
25	79.12	38.08	23.54	13.09
10	61.03	29.85	18.52	10.38
5	46.70	23.34	14.54	8.25
2	25.05	13.50	8.53	5.01

Rainfall Depth (mm)

A17

Station: Suwaydrah **Region:** VI

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49520

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.94970

S. NO.	Duration (min.)			
	10	30	60	120
1	5.20	8.90	9.80	10.40
2	4.00	8.10	8.40	9.50
3	1.80	1.80	1.80	1.80
4	3.60	6.60	8.20	14.80
5	2.00	4.30	6.40	8.60
6	3.60	6.20	6.20	6.20
7	9.80	9.80	10.00	10.00
8	7.80	19.20	21.40	21.80
9	2.80	4.00	6.60	9.20
10	1.00	1.00	1.00	1.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	96.00	59.00	32.50	17.00
50	84.50	51.15	28.07	15.42
25	72.20	43.48	23.92	13.20
10	55.63	33.13	18.33	10.20
5	42.52	24.94	13.90	7.84
2	22.71	12.58	7.22	4.26

Rainfall Depth (mm)

A18

Station: Al Medina **Region:** **VI**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.52200

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 1.05660

S. NO.	Duration (min.)			
	10	30	60	120
1	5.20	11.60	12.30	12.30
2	3.00	6.00	6.90	8.40
3	12.00	18.00	32.30	43.10
4	5.00	9.80	15.60	16.00
5	0.60	1.40	1.40	1.40
6	5.70	8.30	8.50	13.20
7	1.60	2.80	4.60	4.60
8	4.60	4.80	6.00	6.00
9	1.60	2.60	3.00	3.60
10	5.40	5.40	5.40	5.40
11	5.60	6.20	10.80	14.00
12	0.90	2.30	2.60	2.60
13	12.40	17.00	17.50	22.80
14	19.40	27.20	27.20	27.20
15	7.80	14.80	20.60	24.20
16	3.80	4.80	6.80	11.20
17	10.20	10.60	15.60	15.80
18	5.00	10.00	11.80	11.80
19	13.00	14.00	14.00	14.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	153.00	70.00	44.00	27.00
50	133.16	61.11	38.48	23.11
25	113.52	52.28	32.92	19.71
10	87.04	40.38	25.41	15.13
5	66.09	30.97	19.47	11.50
2	31.44	16.74	10.50	6.03

Rainfall Depth (mm)

A19

Station: Kwash **Region: VI**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.51570

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 1.03160

S. NO.	Duration (min.)			
	10	30	60	120
1	15.00	31.00	38.80	38.80
2	19.00	37.80	41.60	41.60
3	22.00	37.60	49.80	51.40
4	49.60	50.00	50.40	51.00
5	15.00	28.20	39.80	39.80
6	15.60	27.80	34.00	34.60
7	20.00	37.00	70.40	74.00
8	16.00	28.50	32.70	32.90
9	18.80	28.00	29.00	29.20
10	18.20	27.60	36.80	38.80
11	11.90	24.50	26.80	26.80
12	14.00	24.00	34.40	34.40
13	15.00	28.40	30.00	30.00
14	13.00	29.00	38.40	39.20
15	14.00	24.00	34.40	34.40
16	4.60	10.20	17.40	19.60

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	328.00	127.00	84.00	43.00
50	290.97	115.01	76.87	39.71
25	252.47	103.42	68.75	35.46
10	200.58	87.79	57.81	29.74
5	159.51	75.42	49.15	25.21
2	97.47	56.74	36.07	18.36

Rainfall Depth (mm)

A20

Station: Kubah **Region:** VI

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.51280

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 1.02057

S. NO.	Duration (min.)			
	10	30	60	120
1	16.00	29.90	39.20	39.20
2	17.00	36.00	42.40	42.40
3	24.10	24.10	24.10	24.10
4	9.20	15.80	16.10	16.10
5	0.20	0.60	0.80	1.20
6	11.80	23.00	29.80	31.20
7	11.00	21.40	27.80	28.60
8	20.00	50.60	63.60	65.20
9	13.00	32.00	33.40	33.60
10	12.20	30.20	31.20	46.50
11	18.20	26.60	41.60	17.70
12	10.00	17.40	17.70	48.20
13	14.00	26.00	34.00	51.80
14	21.80	41.80	51.80	51.80
15	19.20	27.00	38.00	39.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	231.00	146.00	93.00	48.00
50	206.17	130.45	82.91	43.86
25	181.45	114.51	72.50	38.36
10	148.14	93.03	58.48	30.95
5	121.77	76.02	47.37	25.08
2	81.94	50.34	30.60	16.22

Rainfall Depth (mm)

A21

Station: Kiyat **Region: VII**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49960

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.96760

S. NO.	Duration (min.)			
	10	30	60	120
1	4.00	8.10	10.30	10.90
2	5.80	7.30	7.30	7.30
3	6.00	12.00	12.40	12.40
4	16.00	37.00	54.80	54.80
5	3.50	7.80	7.80	7.80
6	12.00	14.60	15.20	15.20
7	11.00	21.00	36.00	55.20
8	2.60	2.60	2.80	3.60
9	12.60	19.00	19.00	20.60
10	15.00	29.40	32.80	33.00
11	9.00	15.60	18.20	20.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	174.00	119.00	85.00	48.00
50	153.52	104.02	74.33	42.99
25	132.78	89.07	63.04	36.37
10	104.82	68.92	47.81	27.44
5	82.68	52.97	35.76	20.37
2	49.26	28.88	17.55	9.69

Rainfall Depth (mm)

A22

Station: Hanakiyah **Region:** **VII**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.51770

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 1.03160

S. NO.	Duration (min.)			
	10	30	60	120
1	5.40	9.60	9.60	9.60
2	2.80	4.40	6.00	8.00
3	5.70	6.20	6.20	6.20
4	4.40	4.40	6.00	6.00
5	0.40	0.40	0.40	0.40
6	2.40	5.50	9.00	10.80
7	4.60	7.60	11.00	17.60
8	4.80	4.80	4.80	4.80
9	3.60	3.60	3.60	3.60
10	2.60	2.60	2.60	4.20
11	2.60	6.00	8.80	11.40
12	15.00	22.00	32.00	47.00
13	3.00	5.80	6.40	8.60
14	8.40	8.40	8.60	8.60
15	20.00	41.40	42.40	42.40
16	13.80	16.60	24.40	26.60

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	167.00	97.00	57.00	33.00
50	144.12	84.73	49.16	29.12
25	121.92	71.00	41.30	24.47
10	92.00	52.49	30.71	18.20
5	68.31	37.84	22.33	13.24
2	32.54	15.71	9.67	5.74

Rainfall Depth (mm)

A23

Station: Murayr **Region: VII**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49960

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.96760

S. NO.	Duration (min.)			
	10	30	60	120
1	1.60	4.40	9.40	13.00
2	6.20	7.20	7.20	8.80
3	16.00	20.40	21.00	21.00
4	3.40	4.00	4.80	5.60
5	3.00	6.40	9.40	13.60
6	0.60	1.60	1.80	1.80
7	5.70	5.70	6.10	9.80
8	3.00	3.60	4.20	4.60
9	3.40	3.40	3.40	3.40
10	5.60	9.40	11.90	12.10
11	1.40	2.00	2.00	2.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	135.00	57.00	30.00	16.50
50	116.21	49.24	26.91	14.80
25	97.81	41.62	22.87	12.64
10	73.01	31.35	17.43	9.73
5	53.38	23.22	13.12	7.42
2	23.74	10.94	6.62	3.94

Rainfall Depth (mm)

A24

Station: Taif **Region:** IX

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.51280

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 1.02057

S. NO.	Duration (min.)			
	10	30	60	120
1	5.00	7.20	9.50	10.70
2	22.20	35.40	44.20	50.00
3	14.80	25.60	26.40	26.40
4	4.60	8.80	12.50	17.20
5	6.20	10.80	14.20	14.20
6	12.00	24.80	30.00	30.00
7	7.60	15.80	24.20	29.80
8	14.00	27.00	37.00	37.20
9	9.80	20.00	23.80	23.80
10	9.00	12.20	20.60	24.00
11	7.20	13.20	16.20	17.20
12	7.20	11.00	16.40	16.40
13	10.00	22.00	33.40	36.60
14	9.40	18.20	22.20	26.00
15	7.80	11.10	16.30	19.60

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	168.00	99.00	67.00	33.00
50	149.01	88.80	55.46	29.86
25	130.27	77.65	48.75	26.29
10	105.01	62.62	39.70	21.47
5	85.02	50.73	32.54	17.65
2	54.82	32.76	21.73	11.89

Rainfall Depth (mm)

A25

Station: Jermuz **Region:** **IX**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.53200

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 1.09610

S. NO.	Duration (min.)			
	10	30	60	120
1	10.60	12.80	17.40	29.20
2	8.20	11.00	16.00	20.60
3	10.00	15.00	19.80	21.60
4	20.00	35.60	36.40	36.40
5	14.00	23.20	25.00	35.00
6	18.00	28.00	48.00	48.00
7	7.40	8.40	9.40	9.40
8	17.00	28.20	30.00	30.00
9	12.00	18.60	20.80	21.60
10	6.80	13.40	17.00	17.00
11	11.00	21.00	20.80	23.80
12	8.80	12.20	13.20	13.20
13	17.00	24.00	31.00	45.00
14	14.00	20.00	23.00	23.00
15	12.60	18.20	22.80	27.60
16	9.60	13.40	15.20	27.40
17	18.40	21.80	22.60	22.80
18	10.00	14.80	15.00	19.40
19	15.00	37.80	41.40	44.60
20	12.00	26.00	52.00	77.40
21	4.60	9.00	11.60	14.40
22	0.60	1.00	1.60	3.00
23	7.20	16.80	18.60	18.60
24	8.00	17.20	17.20	17.20
25	9.00	17.60	19.20	19.20
26	9.00	12.80	18.40	22.80

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	169.00	97.00	64.00	41.50
50	151.43	87.75	57.93	36.15.
25	133.83	77.11	50.55	31.37
10	110.11	62.76	40.59	24.92
5	91.33	51.40	32.72	19.82
2	62.97	34.25	20.82	12.11

Rainfall Depth (mm)

A26

Station: Hema Saysid **Region:** **IX**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.52520

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 1.06960

S. NO.	Duration (min.)			
	10	30	60	120
1	6.00	25.00	25.00	25.00
2	15.20	15.20	15.20	15.20
3	10.00	27.00	27.00	27.00
4	16.00	16.00	19.00	19.00
5	17.00	40.00	55.00	55.00
6	6.00	6.80	6.80	8.00
7	11.00	17.40	18.40	18.40
8	11.60	23.60	45.00	52.20
9	11.00	13.60	20.80	22.40
10	7.60	16.60	18.00	18.00
11	12.60	16.00	29.00	29.00
12	8.60	11.80	23.00	25.80
13	15.00	31.40	31.40	31.40
14	10.00	25.40	25.40	25.40
15	6.40	9.00	11.80	20.00
16	6.40	25.80	35.00	35.00
17	6.80	10.60	10.60	10.60
18	12.20	24.60	34.20	46.20
19	18.20	24.60	24.60	24.60
20	6.20	11.20	11.20	11.20
21	2.40	5.20	8.40	12.80

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	159.00	105.00	69.00	38.00
50	142.88	93.52	61.76	33.07
25	125.98	81.91	53.80	28.82
10	103.21	66.26	43.00	23.09
5	85.18	53.88	34.59	18.56
2	57.96	35.17	21.77	11.70

Rainfall Depth (mm)

A27

Station: Wadi Dahiyah **Region:** **IX**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.52960

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 1.08640

S. NO.	Duration (min.)			
	10	30	60	120
1	12.00	29.00	44.00	60.00
2	11.60	20.60	29.20	29.20
3	11.00	18.80	31.00	47.20
4	14.00	20.00	28.60	29.80
5	4.00	8.20	8.80	10.20
6	13.00	21.00	27.00	27.00
7	14.20	37.80	48.40	51.60
8	12.00	24.00	28.20	32.20
9	14.00	27.80	38.20	38.20
10	12.00	17.00	27.00	27.00
11	11.40	25.40	26.20	26.20
12	9.00	19.00	25.00	25.00
13	15.60	30.60	47.00	48.80
14	11.00	28.60	36.00	39.60
15	14.00	24.20	35.40	37.40
16	7.00	14.00	24.00	32.00
17	14.00	22.80	27.00	36.00
18	14.20	32.80	36.40	33.00
19	12.80	28.40	33.00	31.60
20	14.40	29.60	20.80	21.60
21	12.40	15.80	15.80	16.40
22	12.80	23.60	28.00	28.40
23	14.00	31.20	37.60	37.60
24	5.40	11.00	11.00	11.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
100	137.00	100.00	66.50	38.00
50	125.64	91.47	60.59	34.87
25	114.34	82.15	54.16	30.99
10	99.10	69.58	45.49	25.77
5	87.01	59.63	38.62	21.64
2	68.83	44.60	28.26	15.39

Rainfall Depth (mm)

A28

Station: Ain Aziziayh **Region:** **IX**

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.51280

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 1.02057

S. NO.	Duration (min.)			
	10	30	60	120
1	6.00	9.20	10.00	10.80
2	9.00	10.40	10.40	10.40
3	12.00	13.80	13.80	13.80
4	2.20	2.80	2.80	2.80
5	10.20	20.20	39.20	59.40
6	8.80	24.80	36.40	36.40
7	7.20	16.20	24.00	30.20
8	5.00	6.60	6.60	6.60
9	11.00	14.80	15.20	15.20
10	10.00	11.20	11.20	11.20
11	2.60	5.00	8.00	9.60
12	7.80	17.00	20.40	21.60
13	4.20	4.60	4.60	5.40
14	3.60	3.60	3.60	4.20
15	5.80	7.60	8.00	12.00

Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

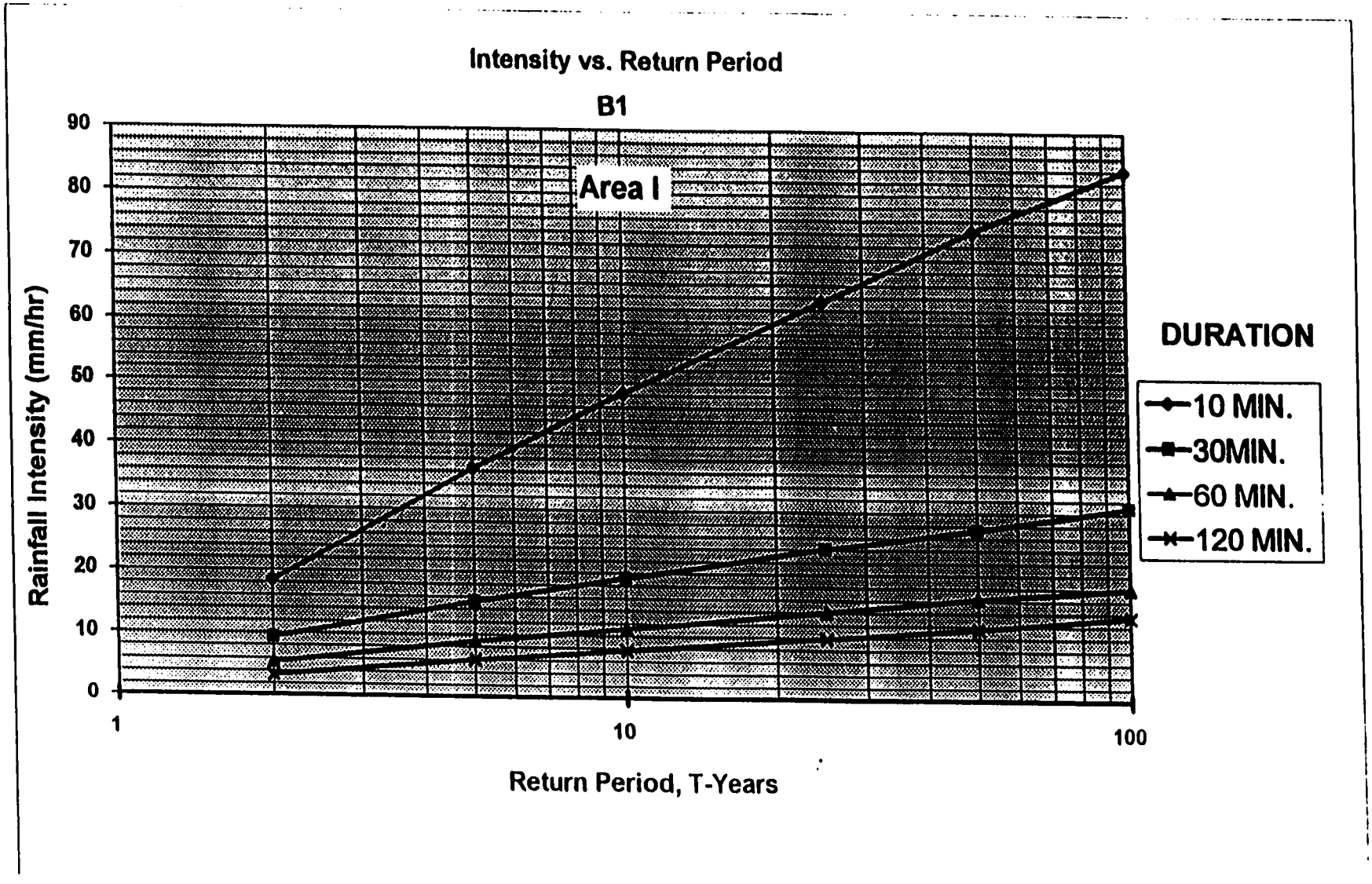
Return period Years	Duration (min.)			
	10	30	60	120
100	117.00	74.00	59.00	38.00
50	104.35	65.61	51.55	33.36
25	91.44	56.64	43.82	28.17
10	74.44	44.54	33.39	21.16
5	60.27	34.97	25.14	15.61
2	39.48	20.51	12.67	7.24

APPENDIX B

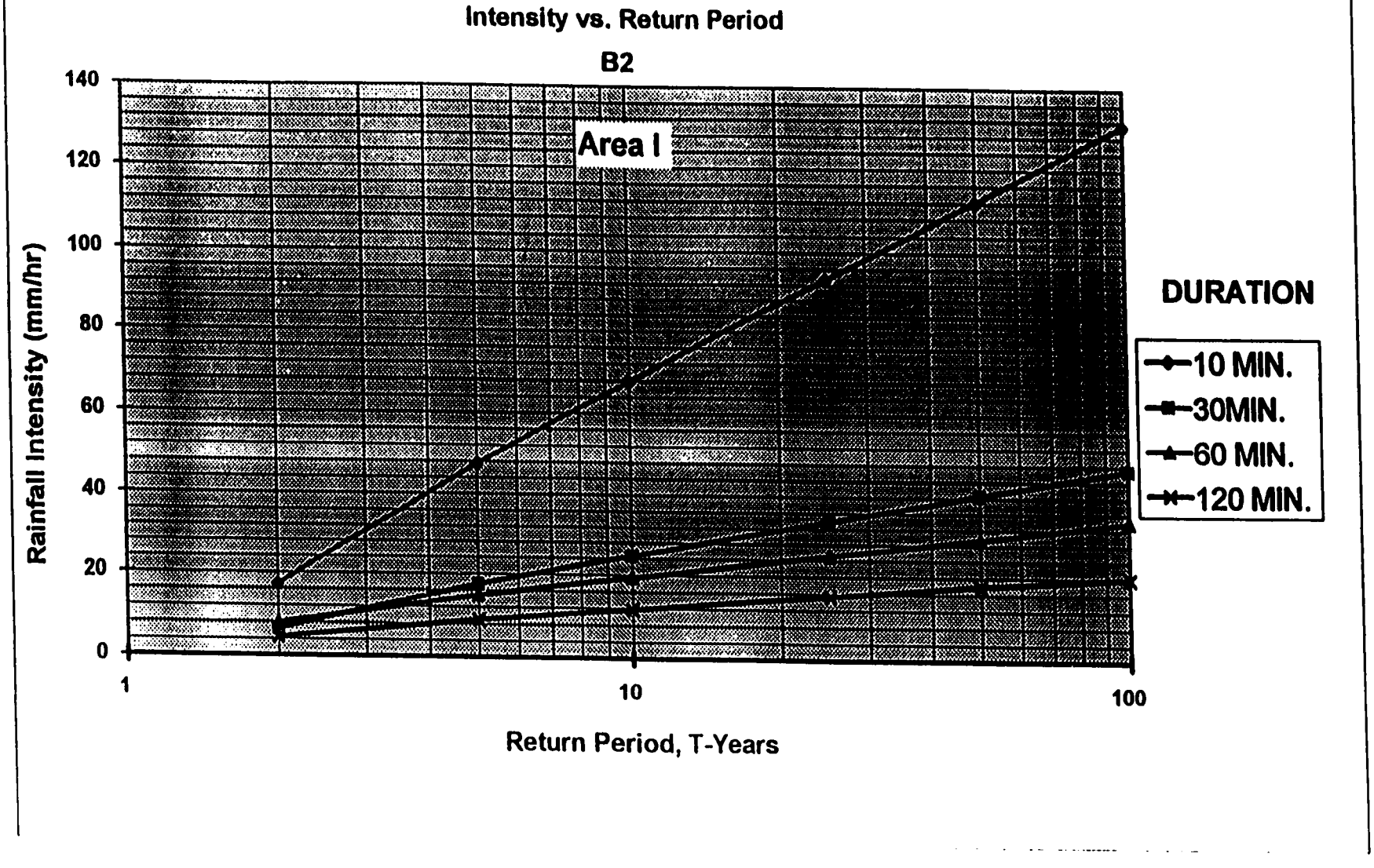
B_1 - B_{28}

INTENSITY / DURATION CURVES

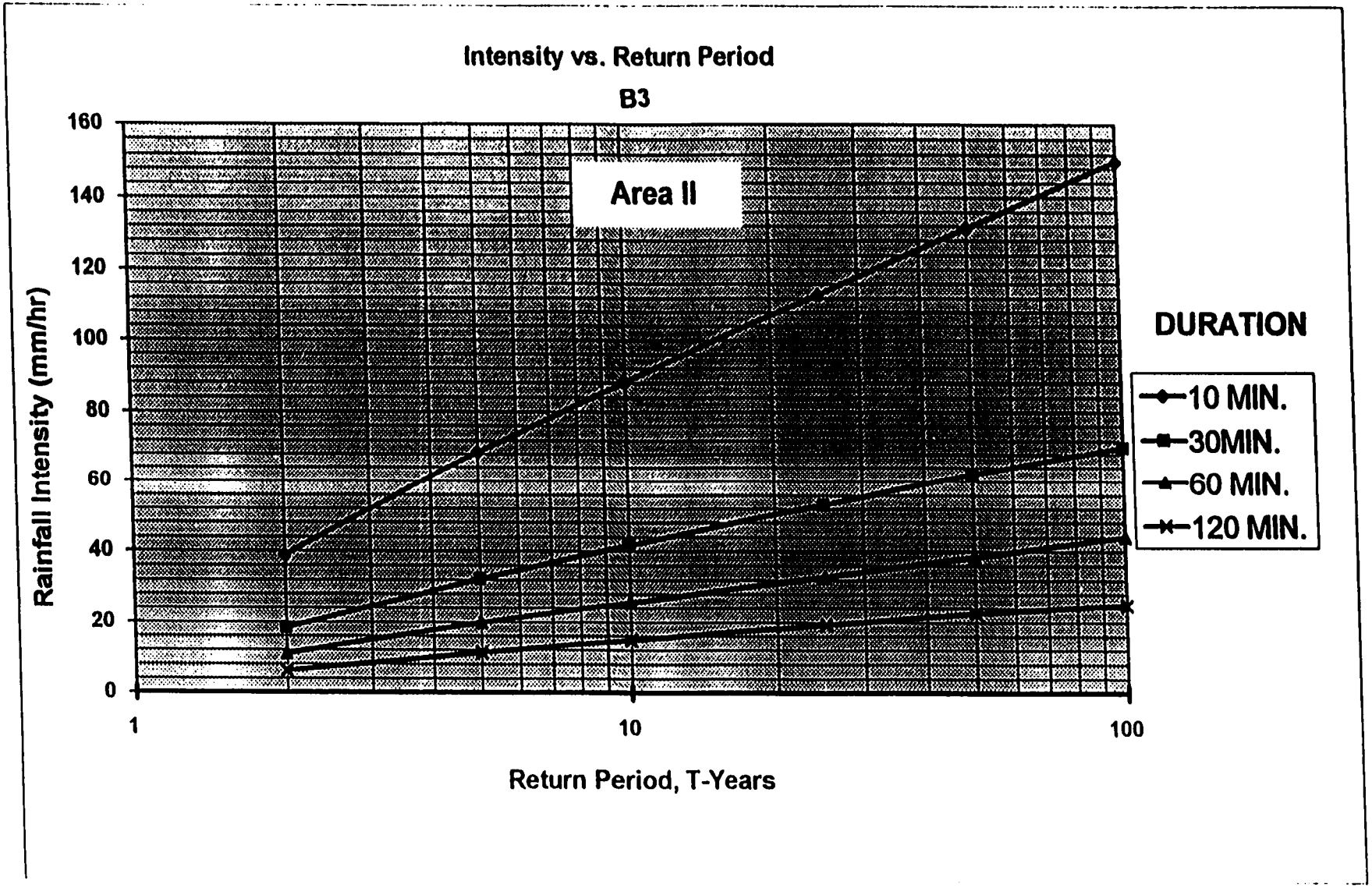
TABUK STATION



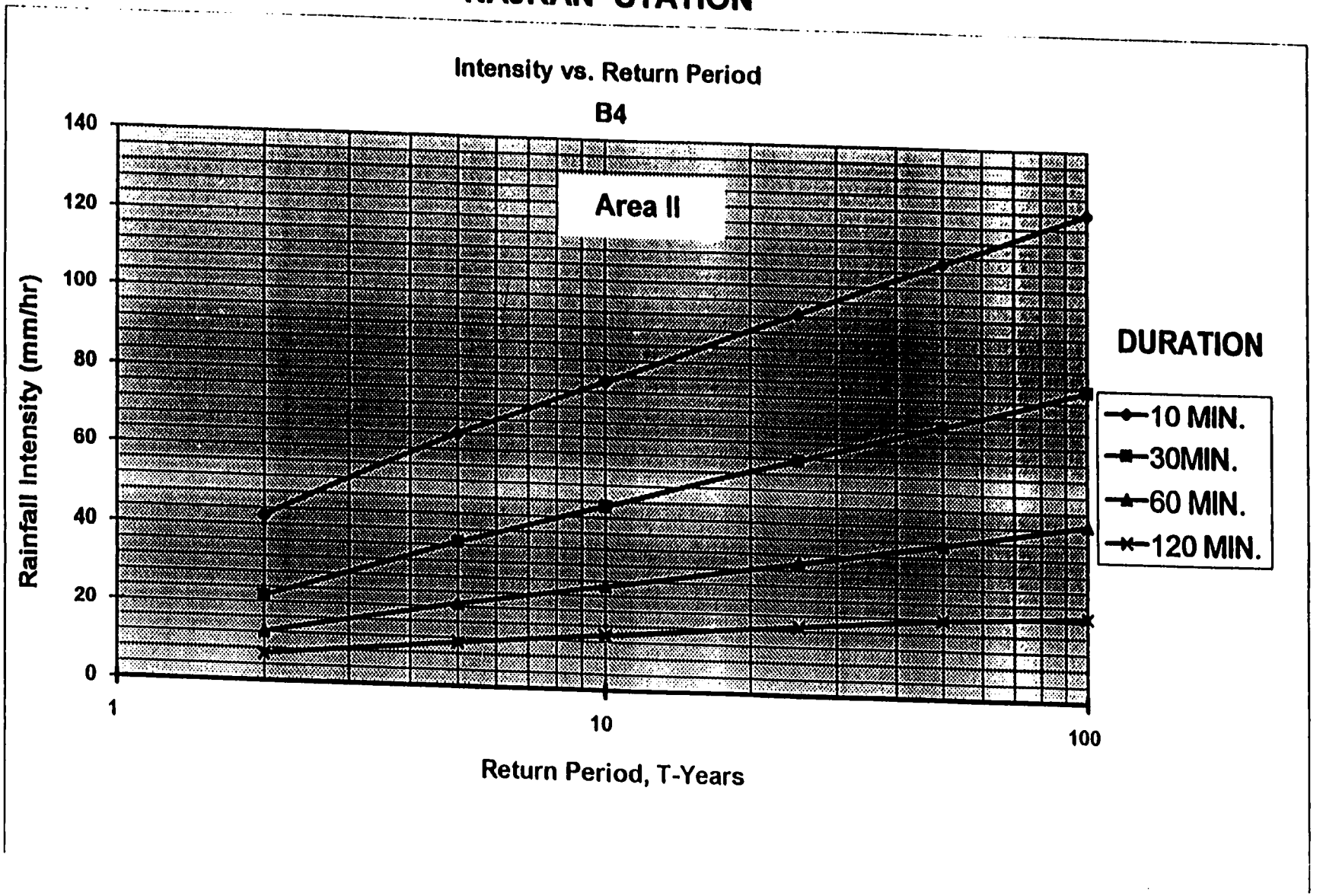
SAKKAKAH STATION



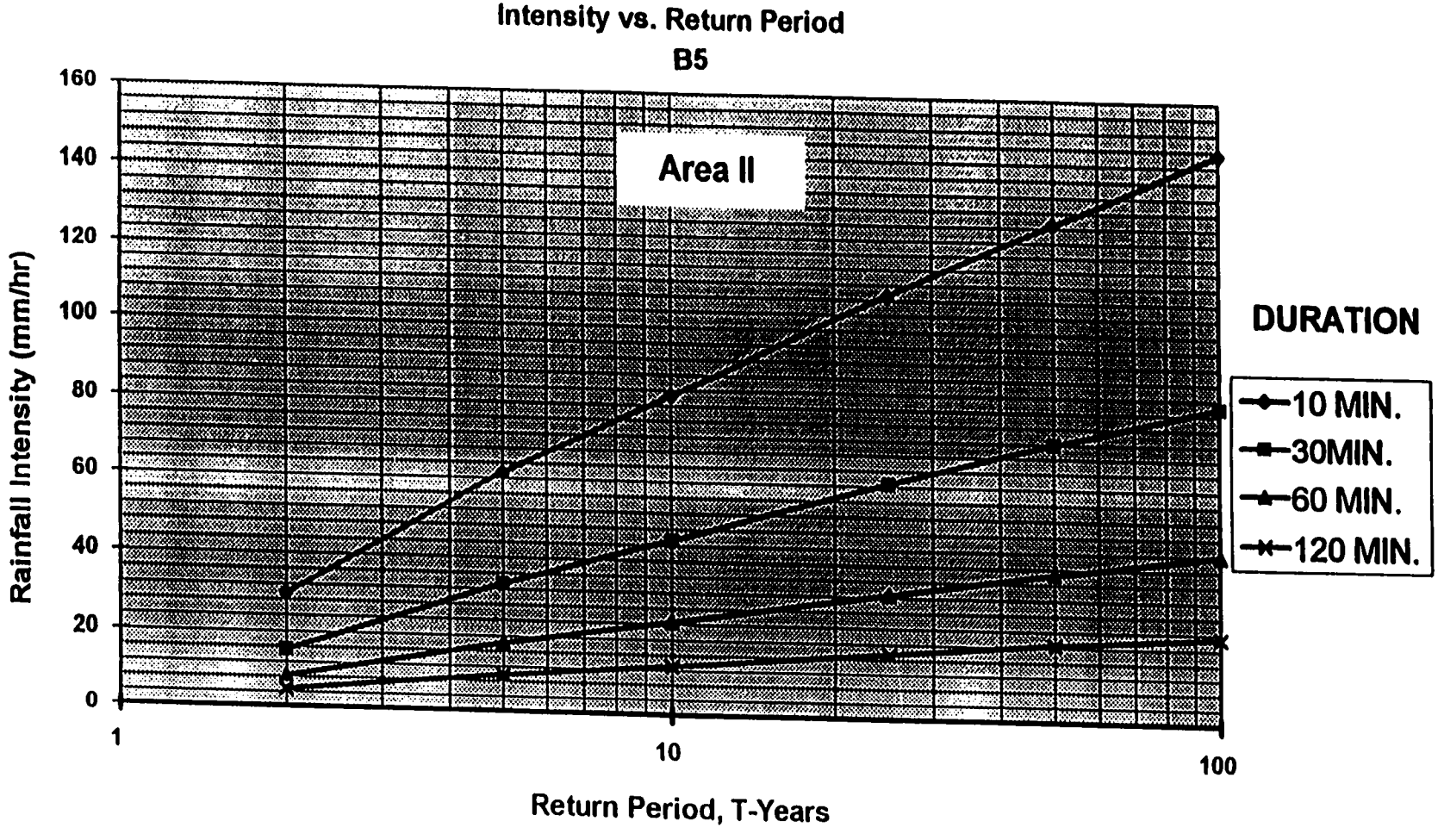
SULAYYIL STATION



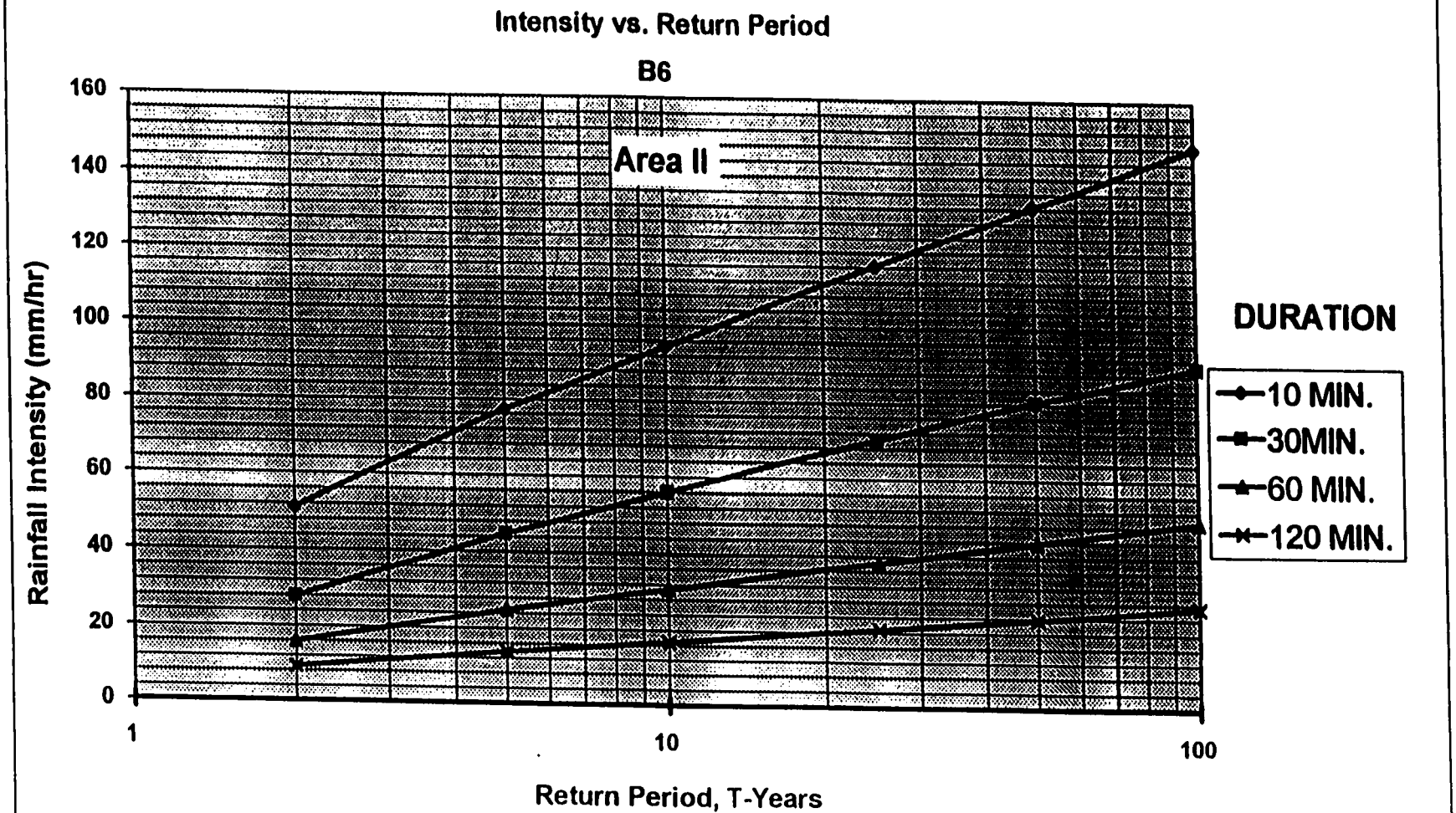
NAJRAN STATION



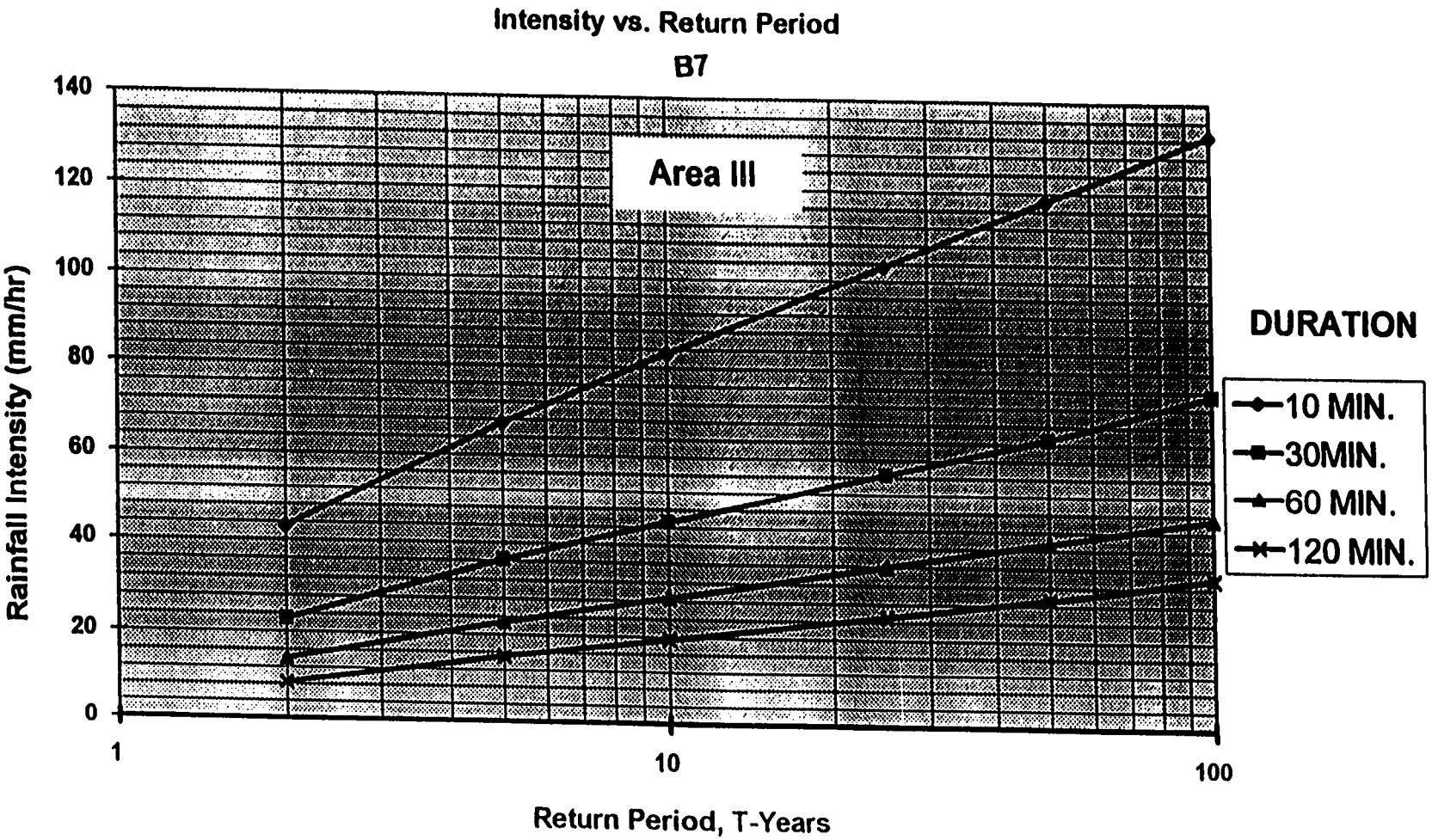
AL AIN QATAN STATION



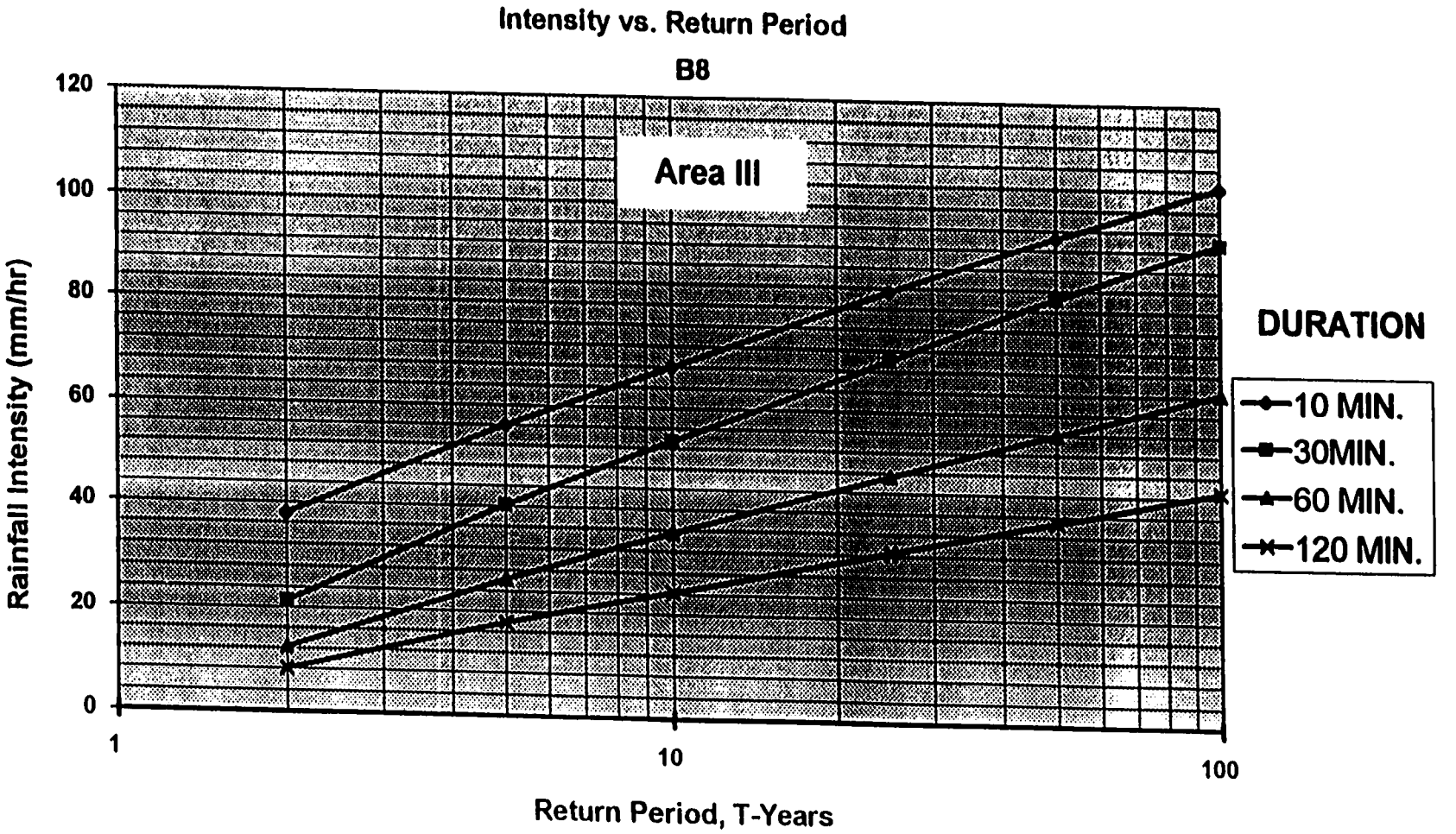
THAWILA STATION



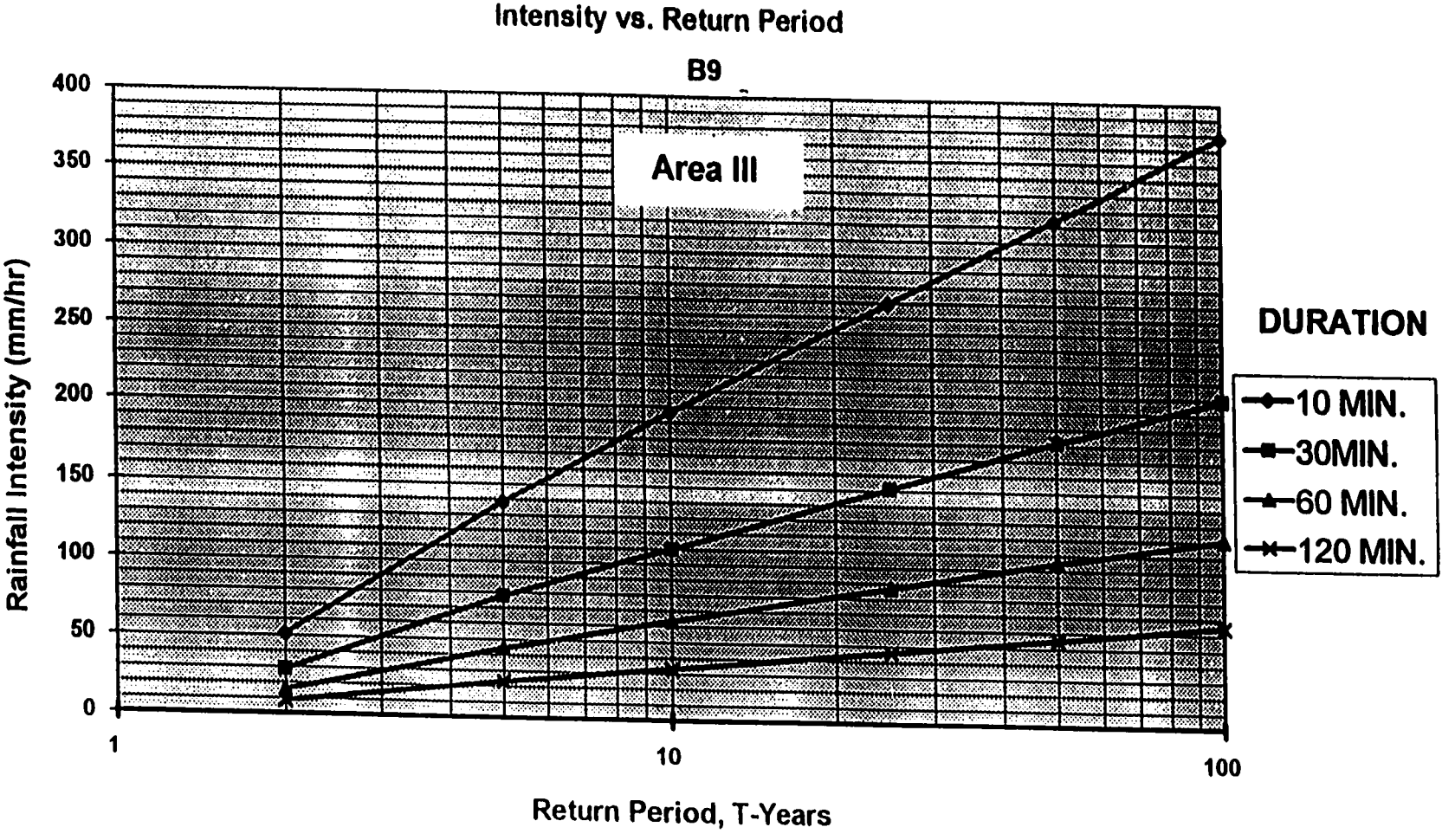
SERAT ABIDA STATION



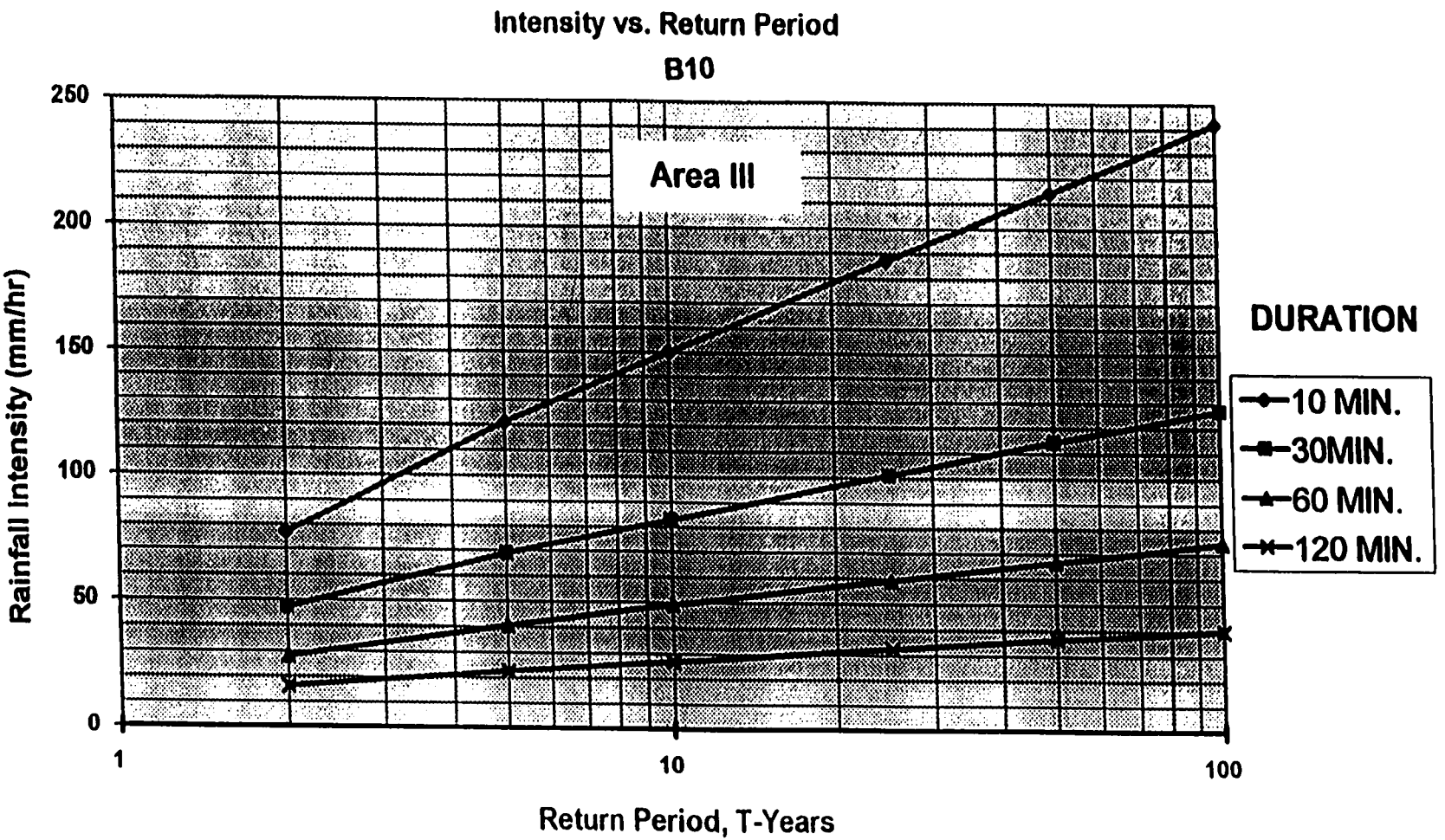
ABU JINNAHA STATION



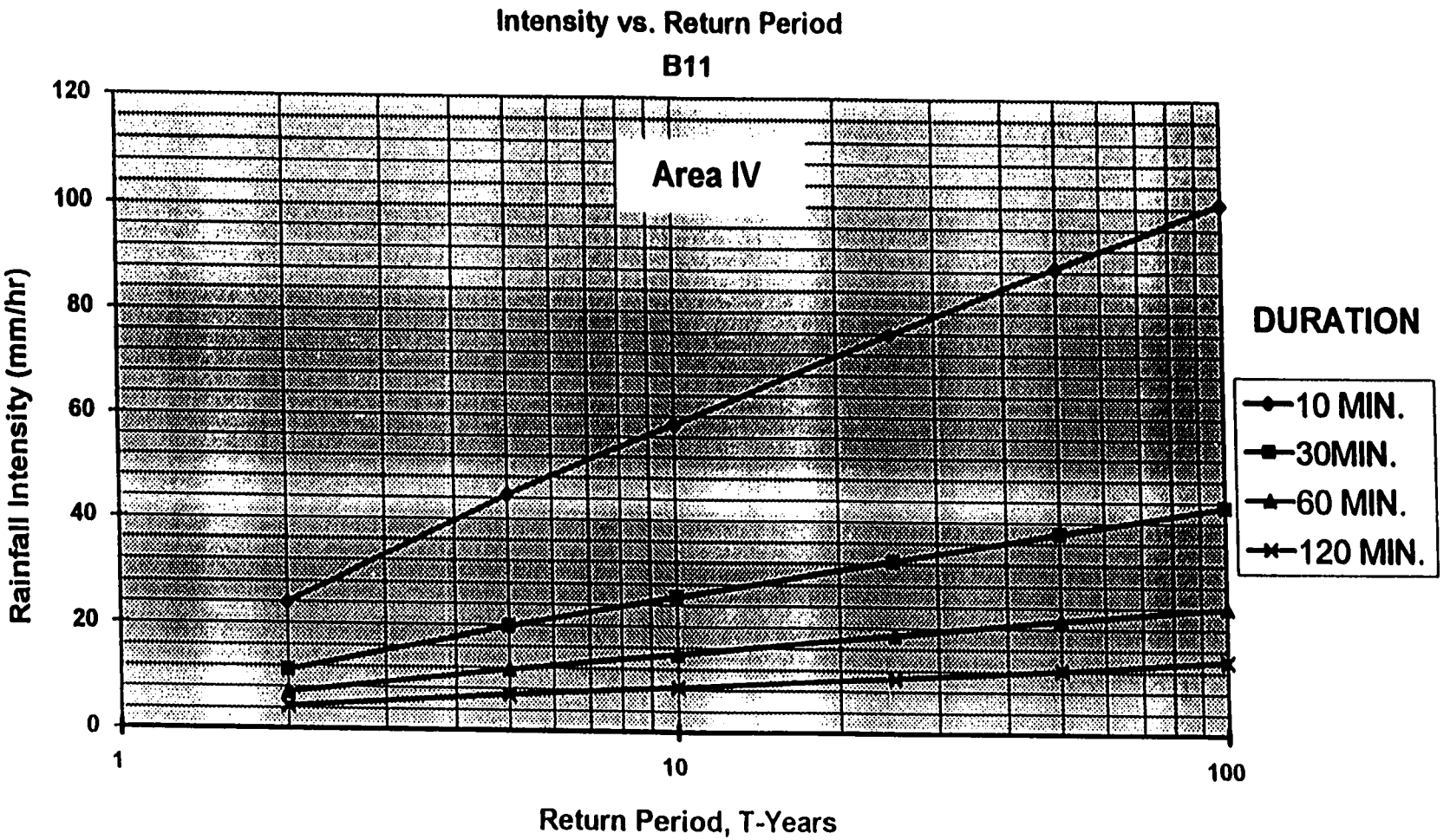
BISHAH STATION



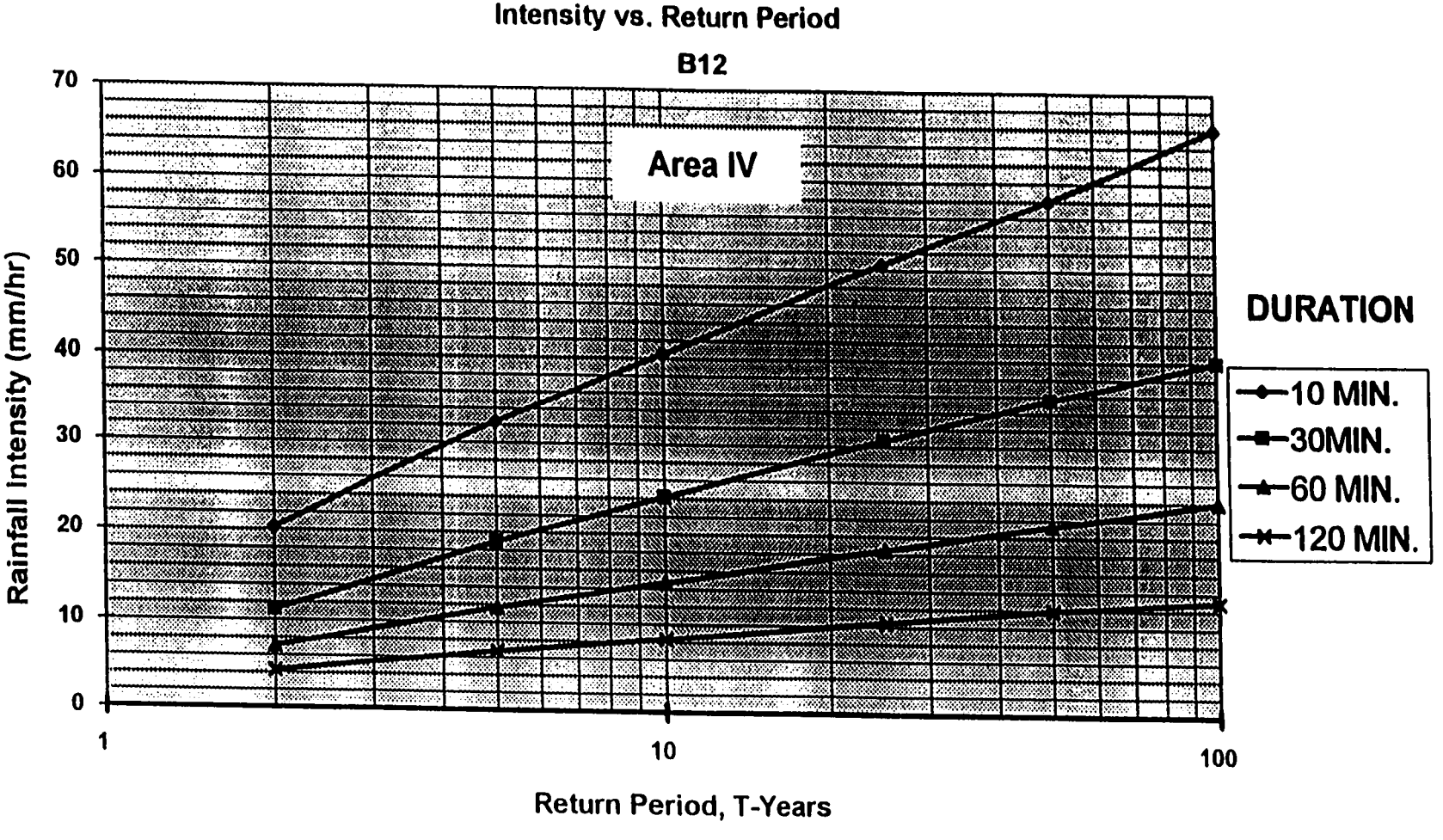
AIN NIMAS STATION



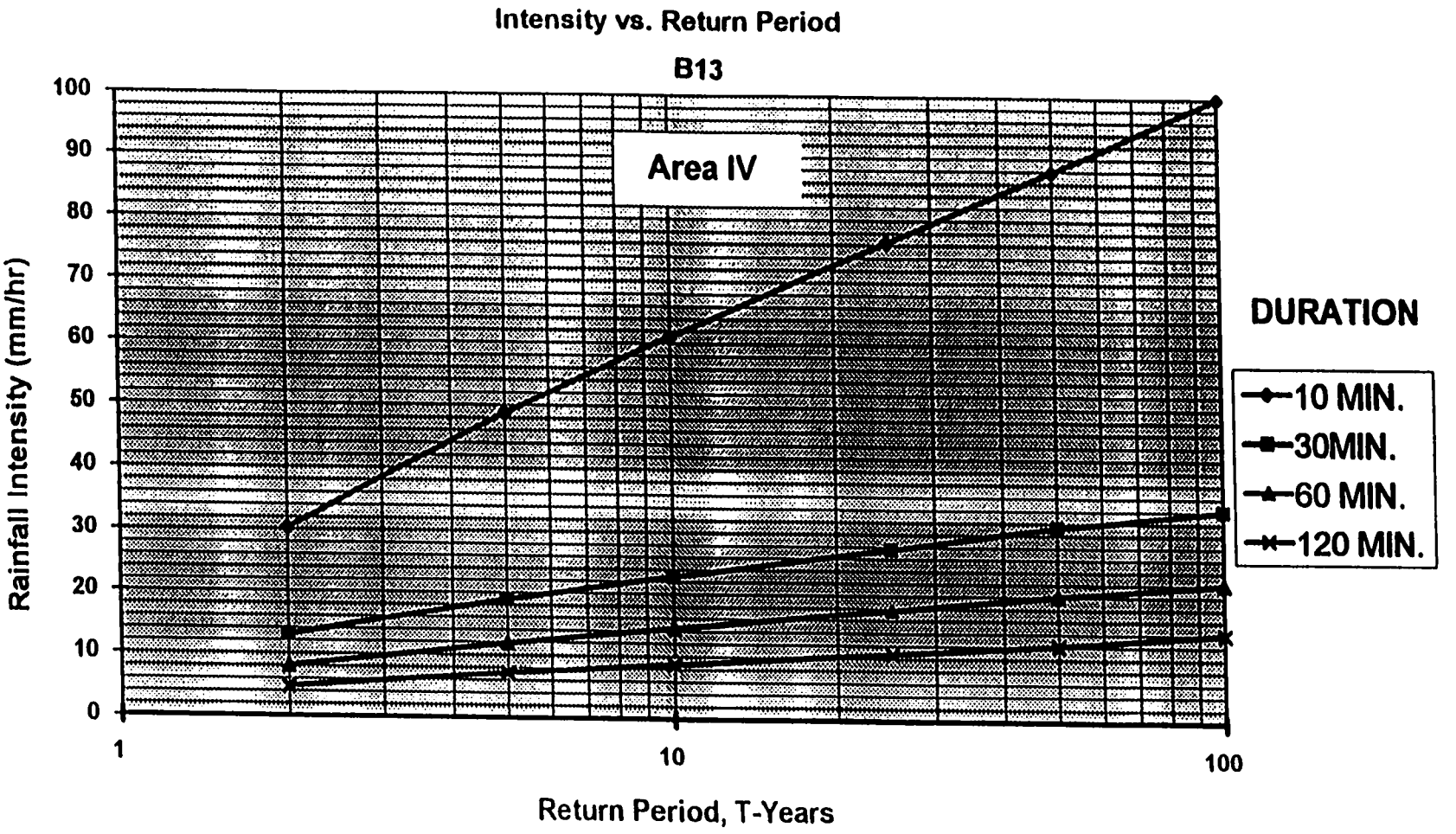
YABRIN STATION



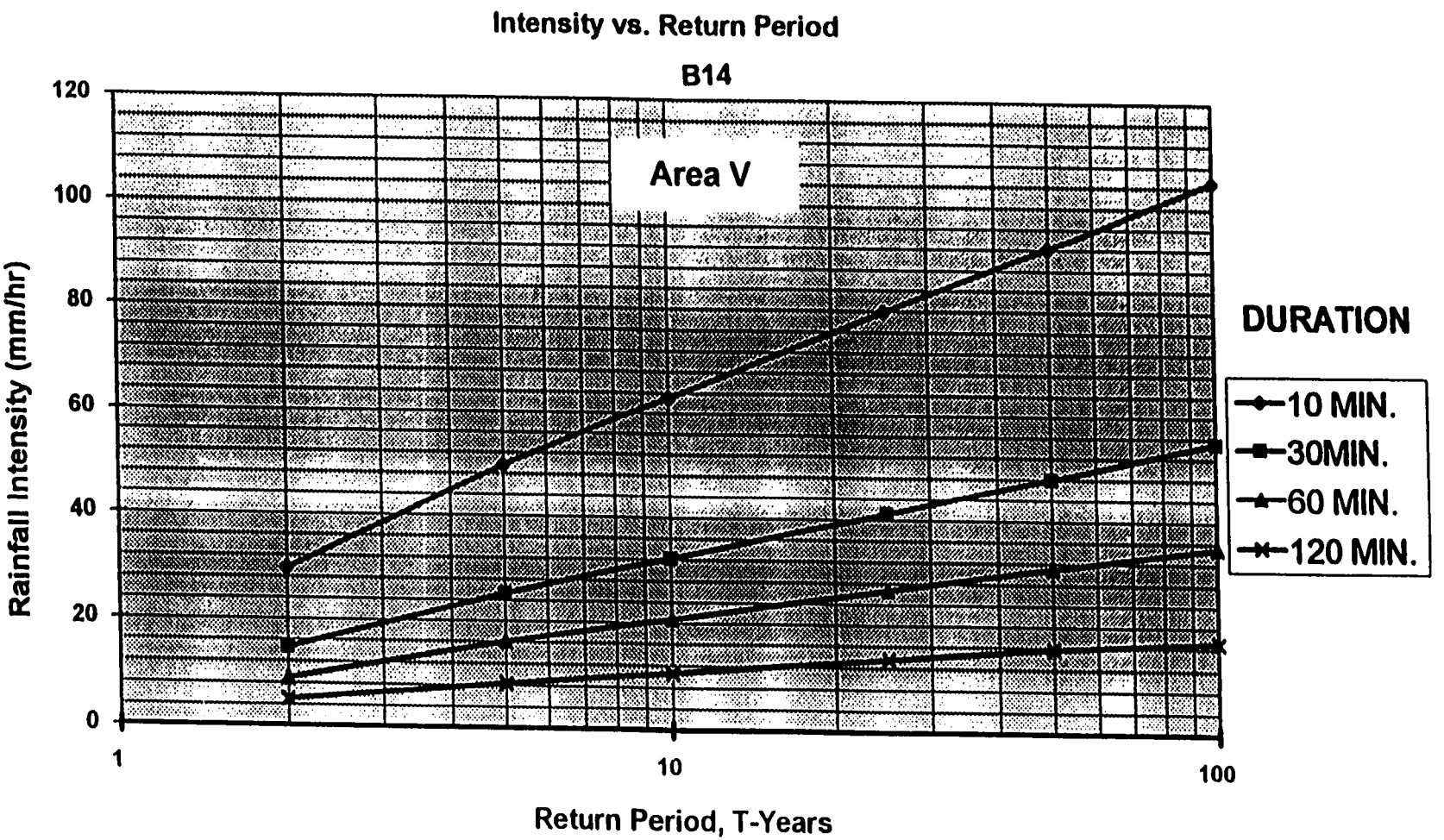
HARADAH STATION



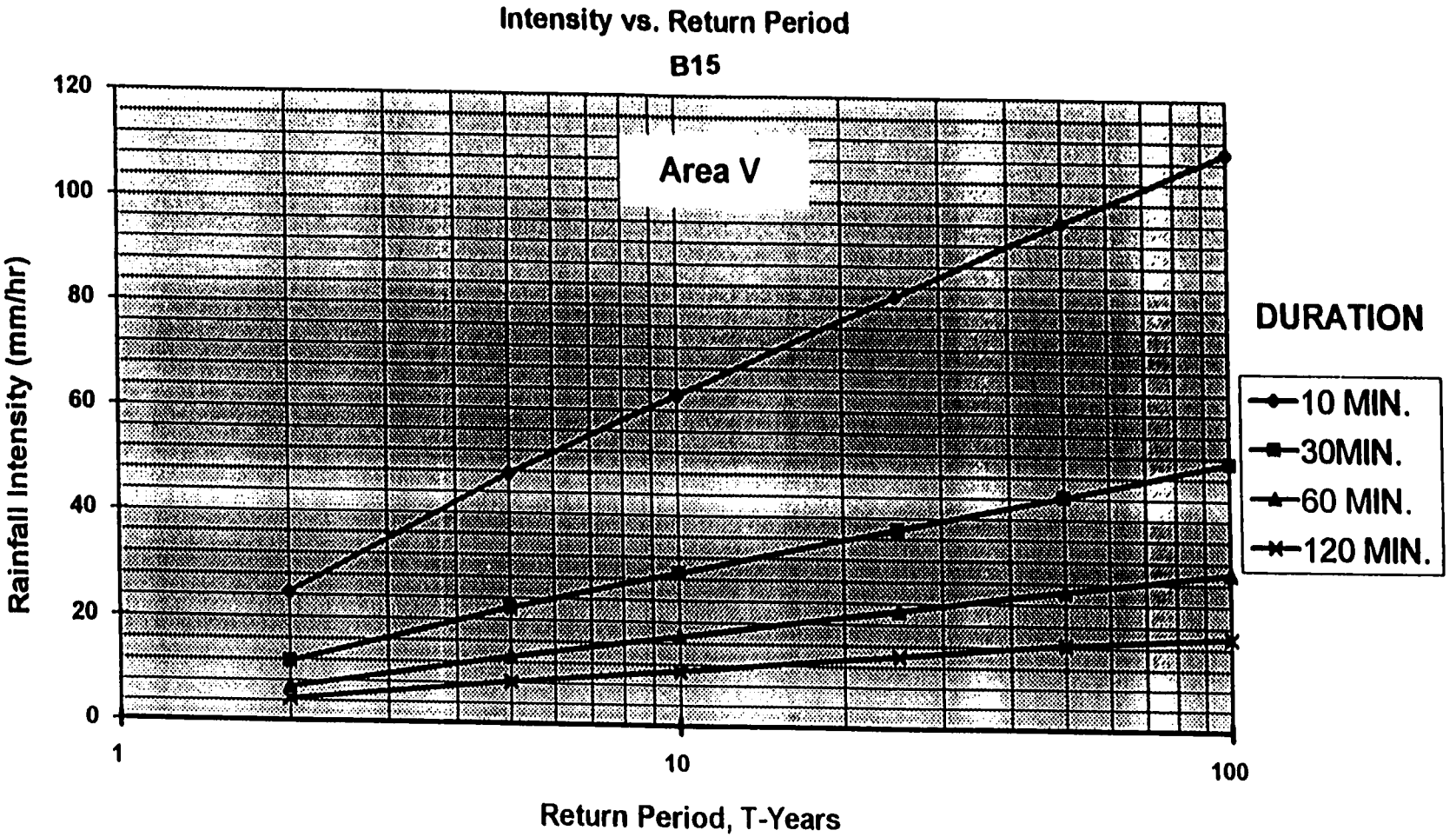
ALSARRAR STATION



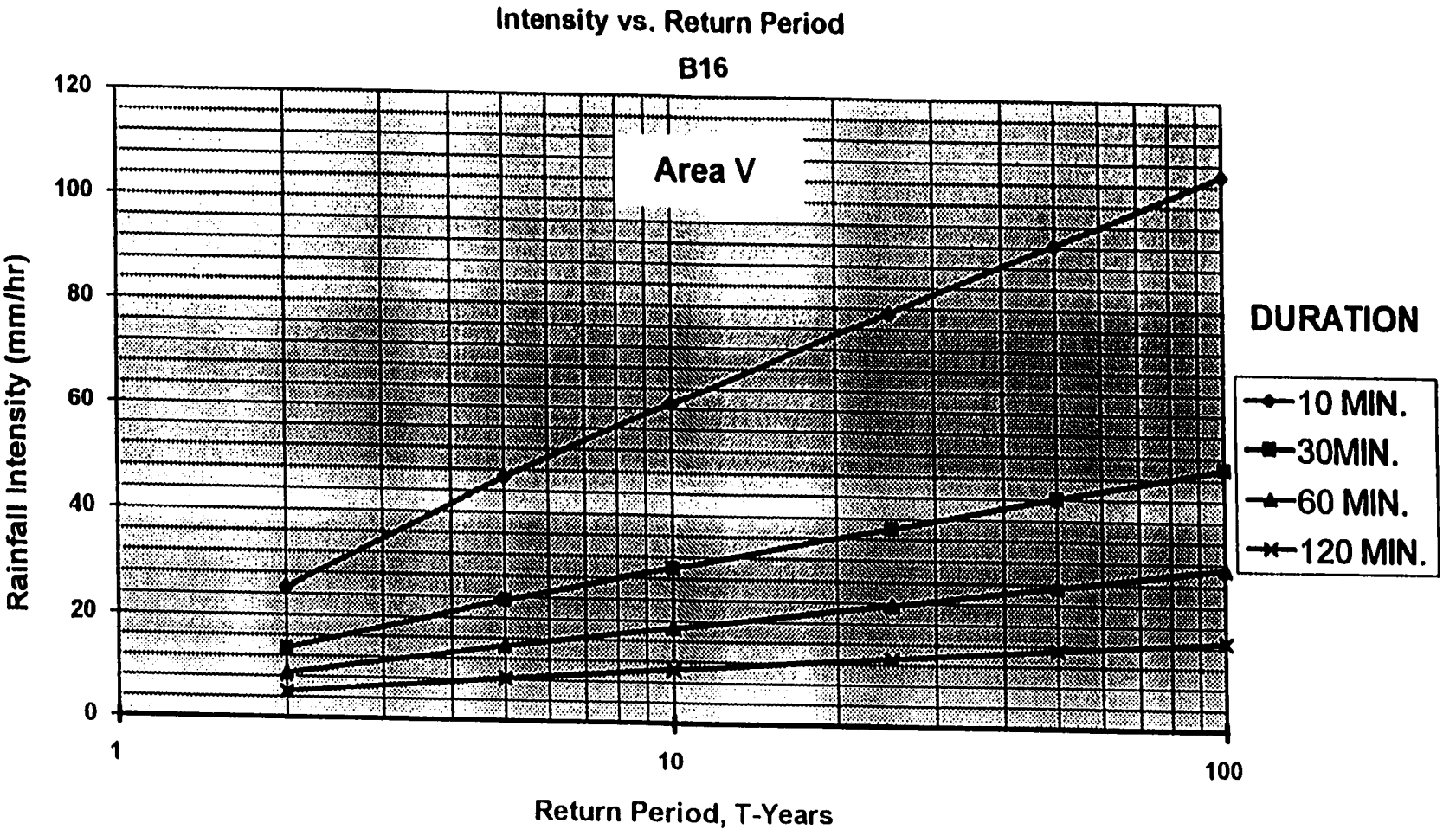
KHURAIS STATION



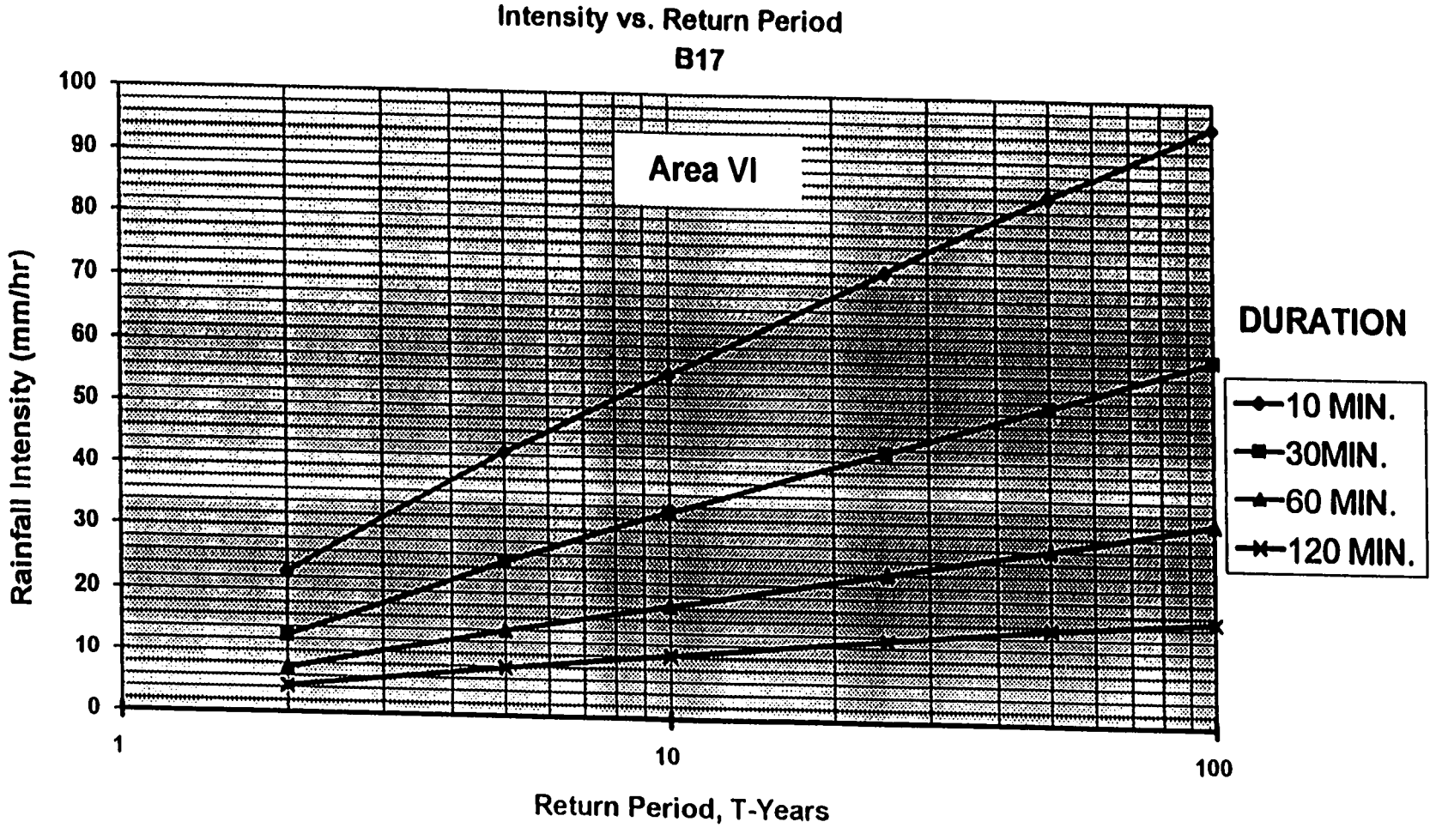
ALKHARJ STATION



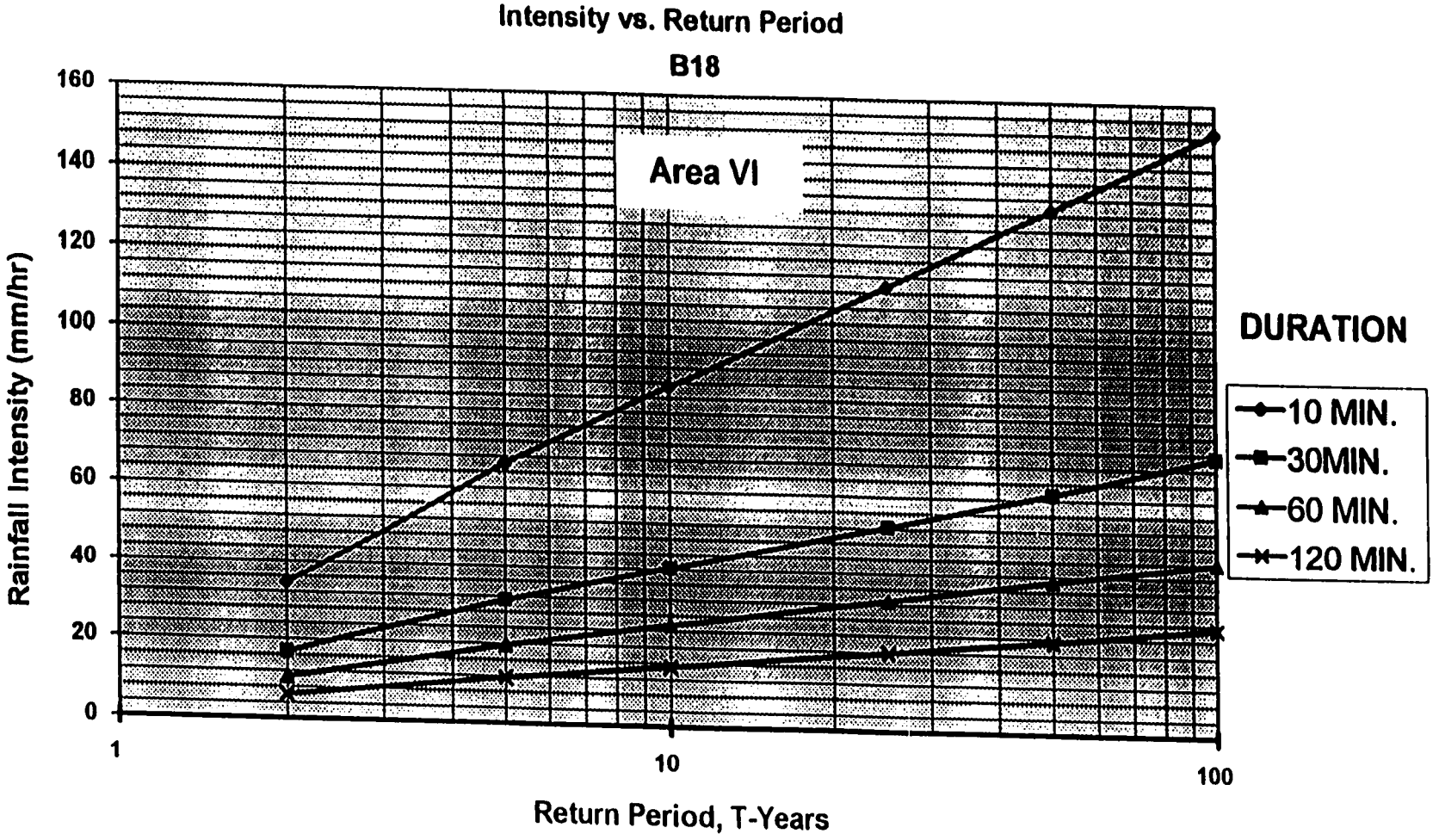
RIYADAH STATION



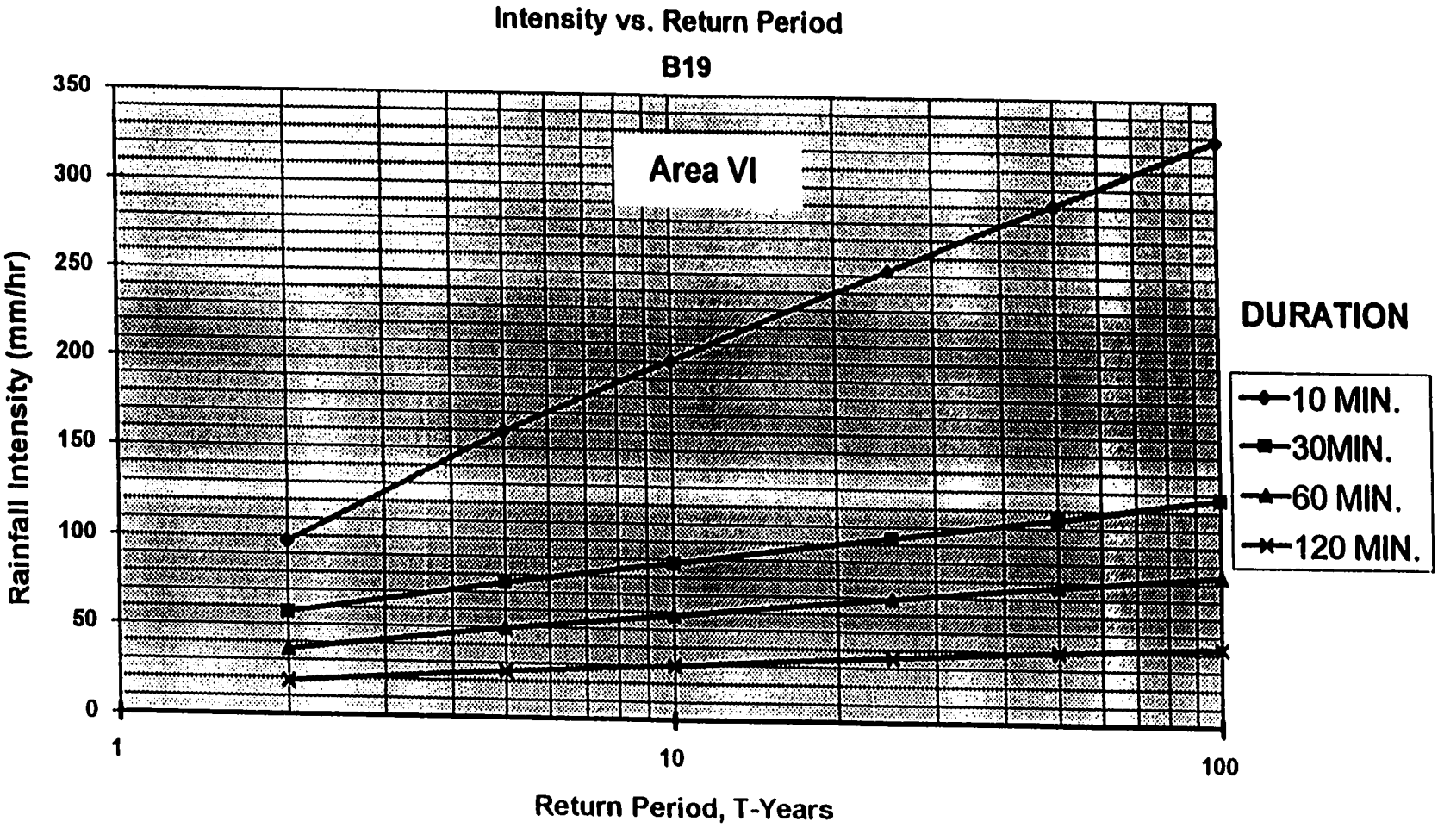
SUWAYDRAH STATION



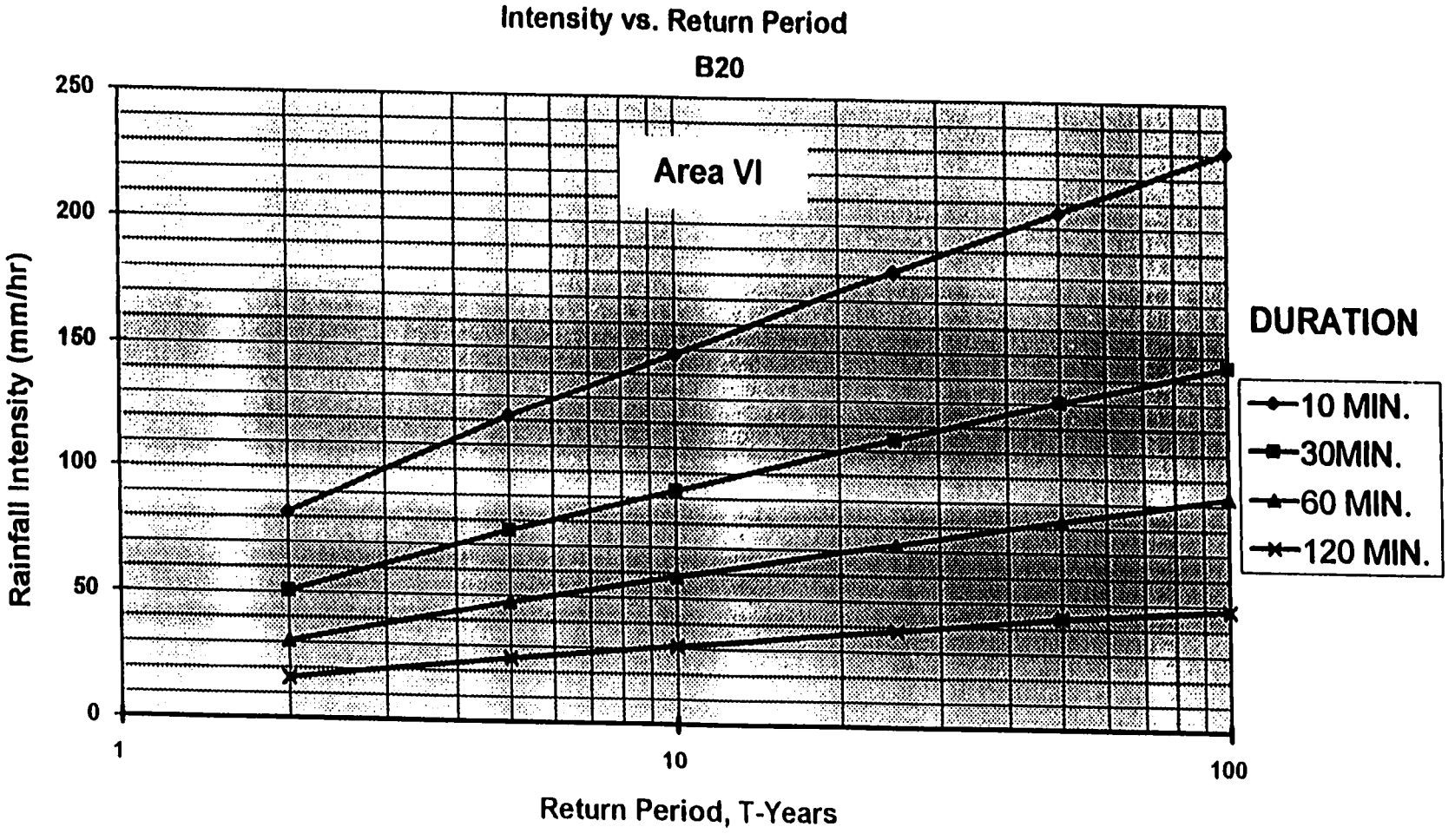
AL MEDINA FARM STATION



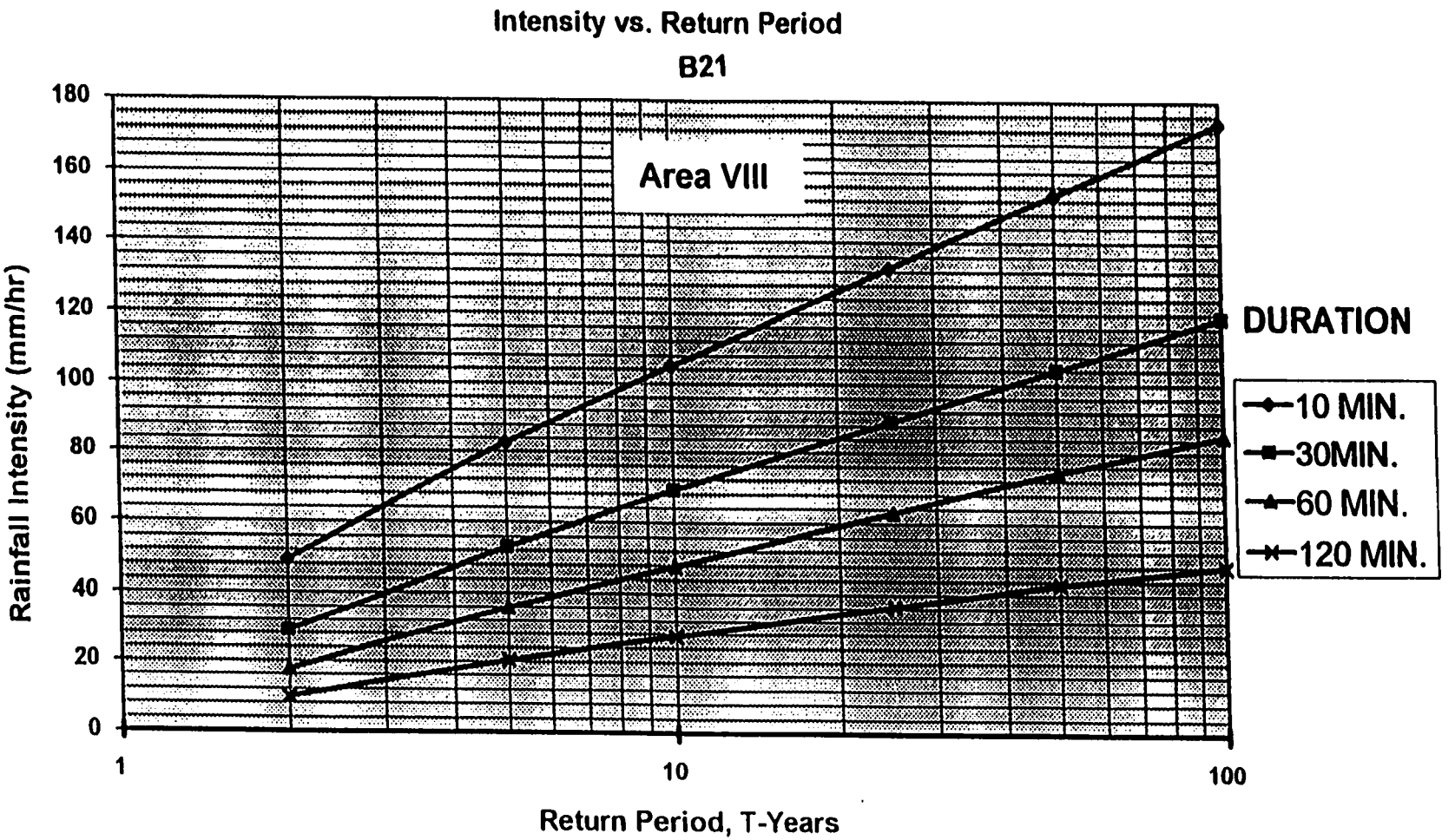
KWASH STATION



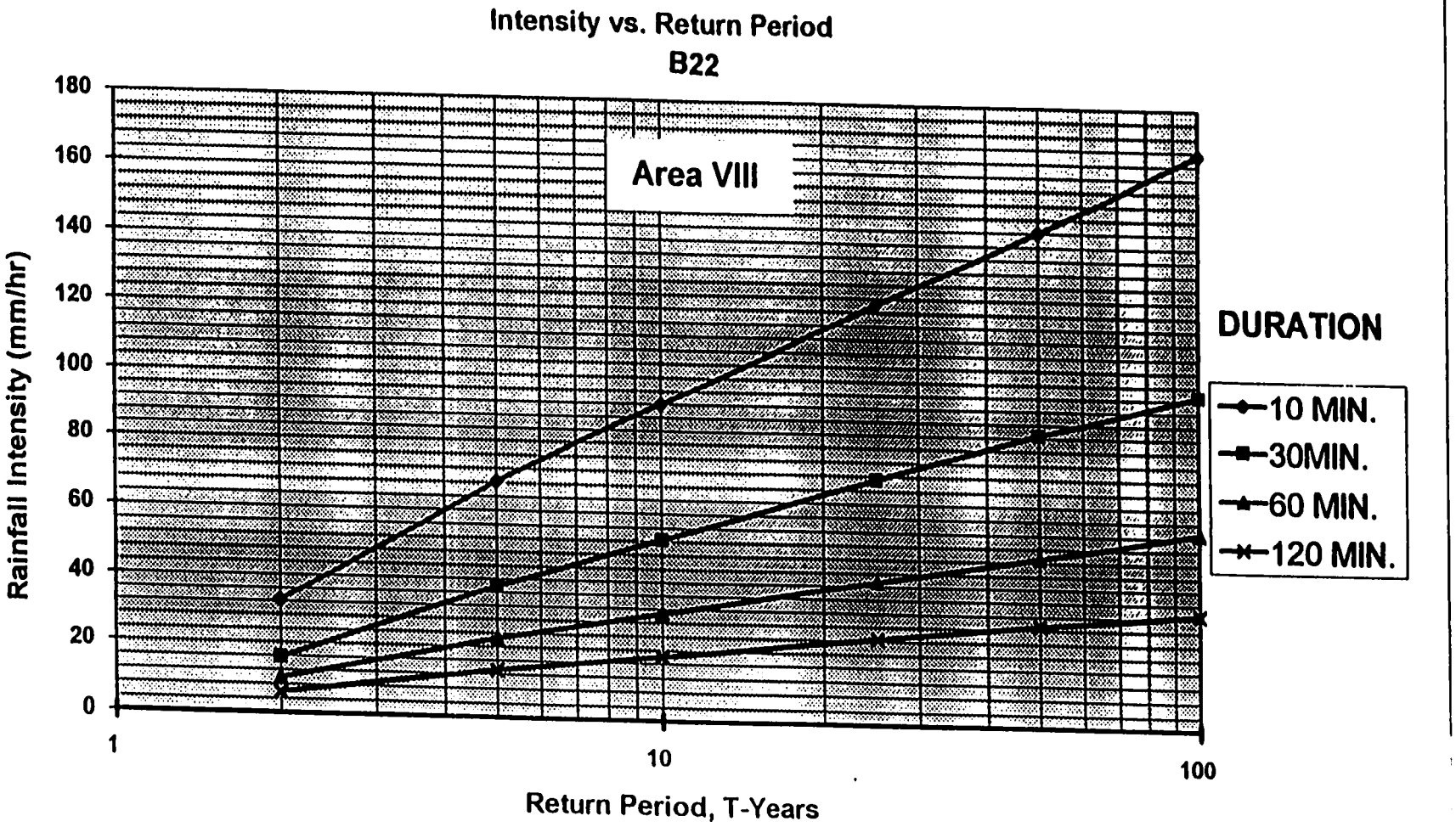
KHUBAH STATION



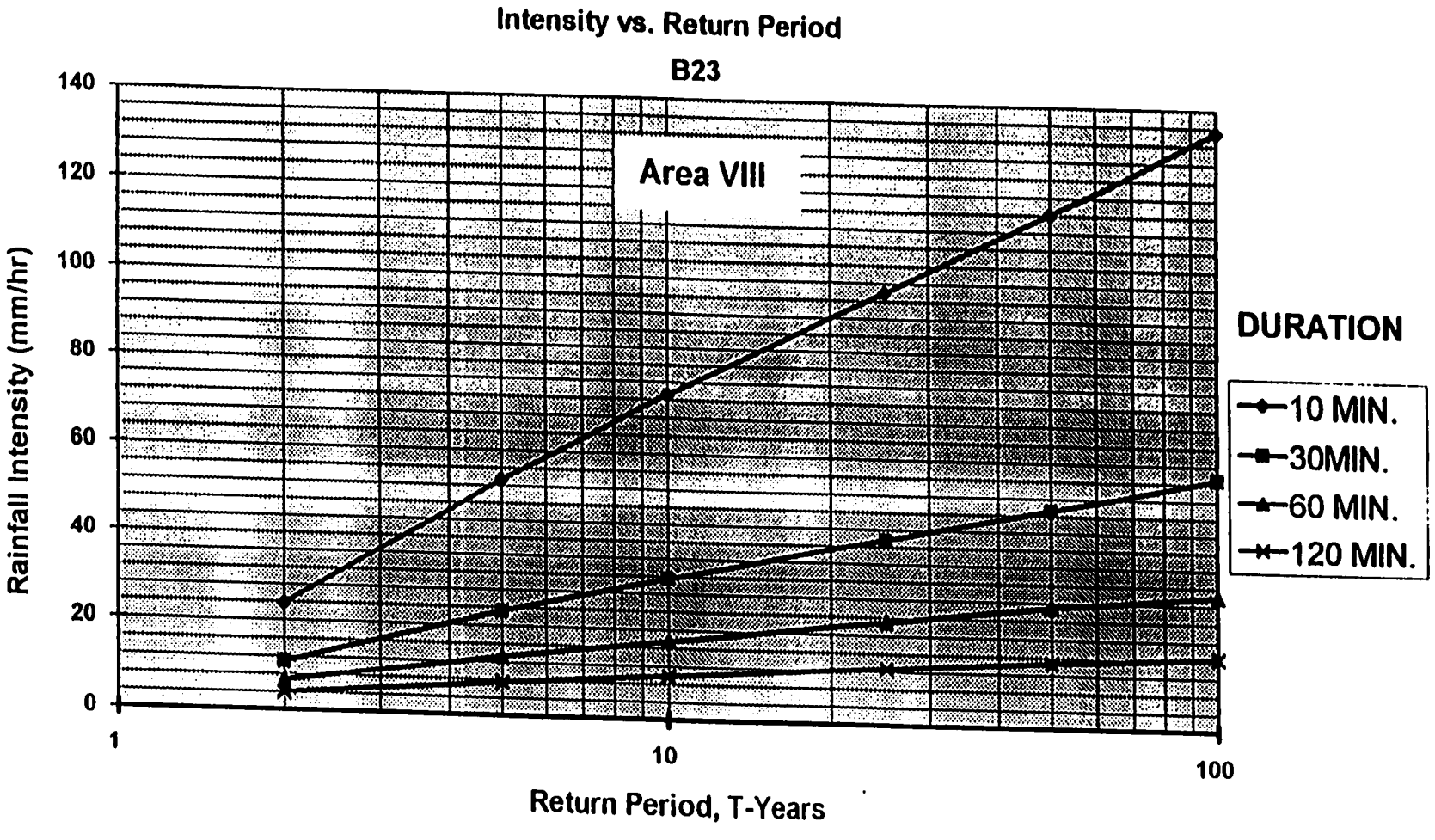
KIYAT STATION



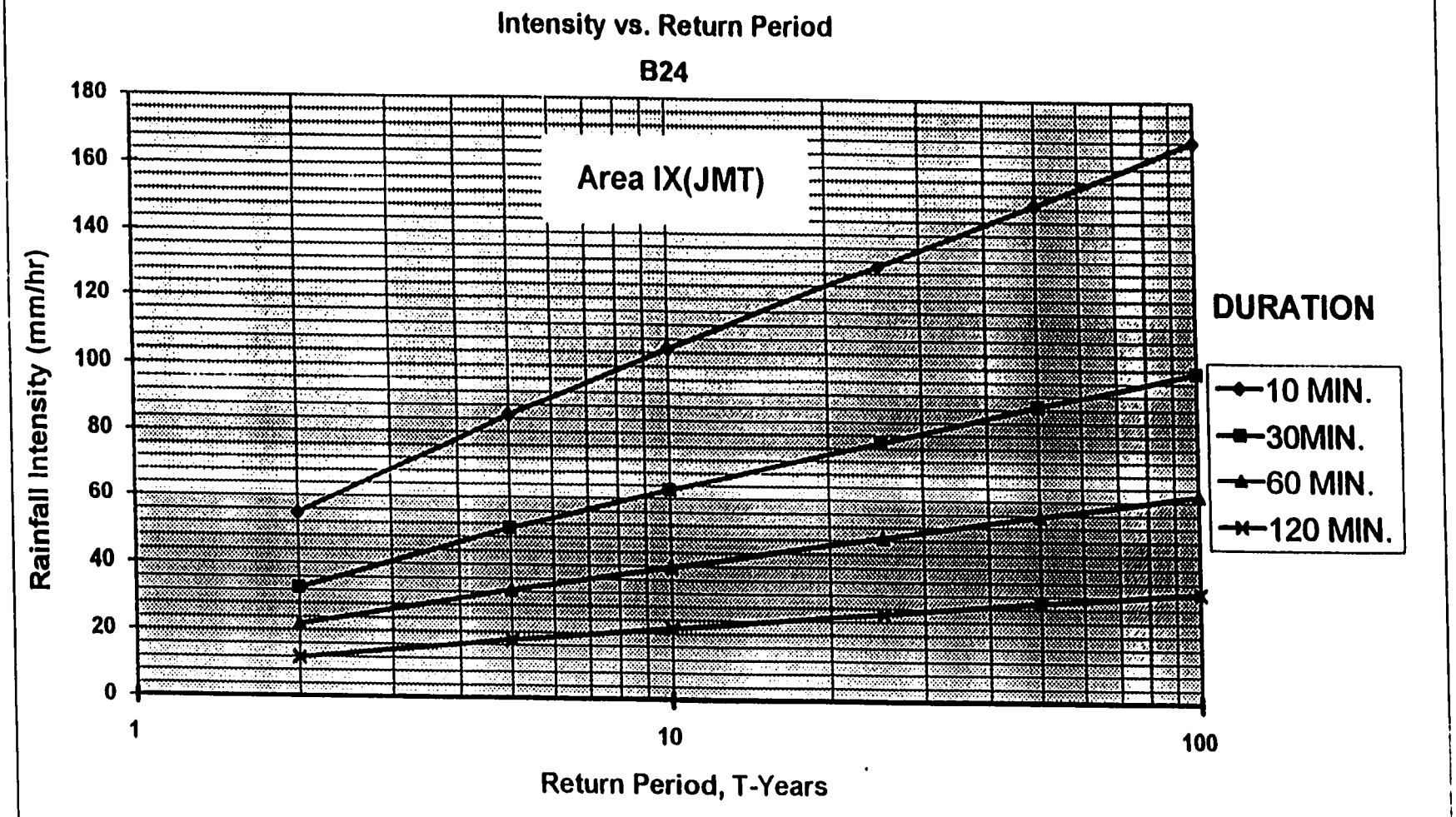
HANAKIYAH STATION



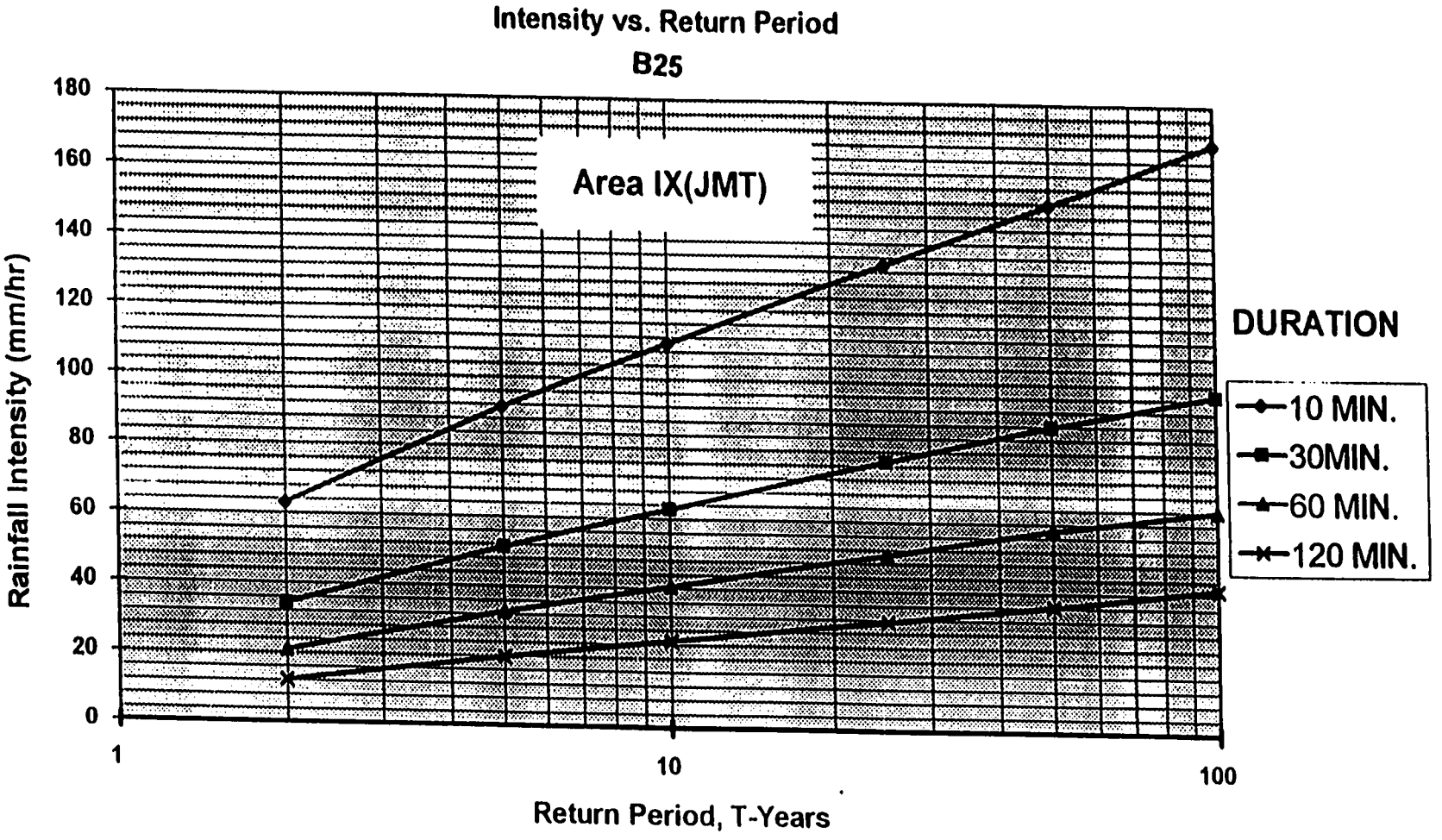
MURAYR STATION



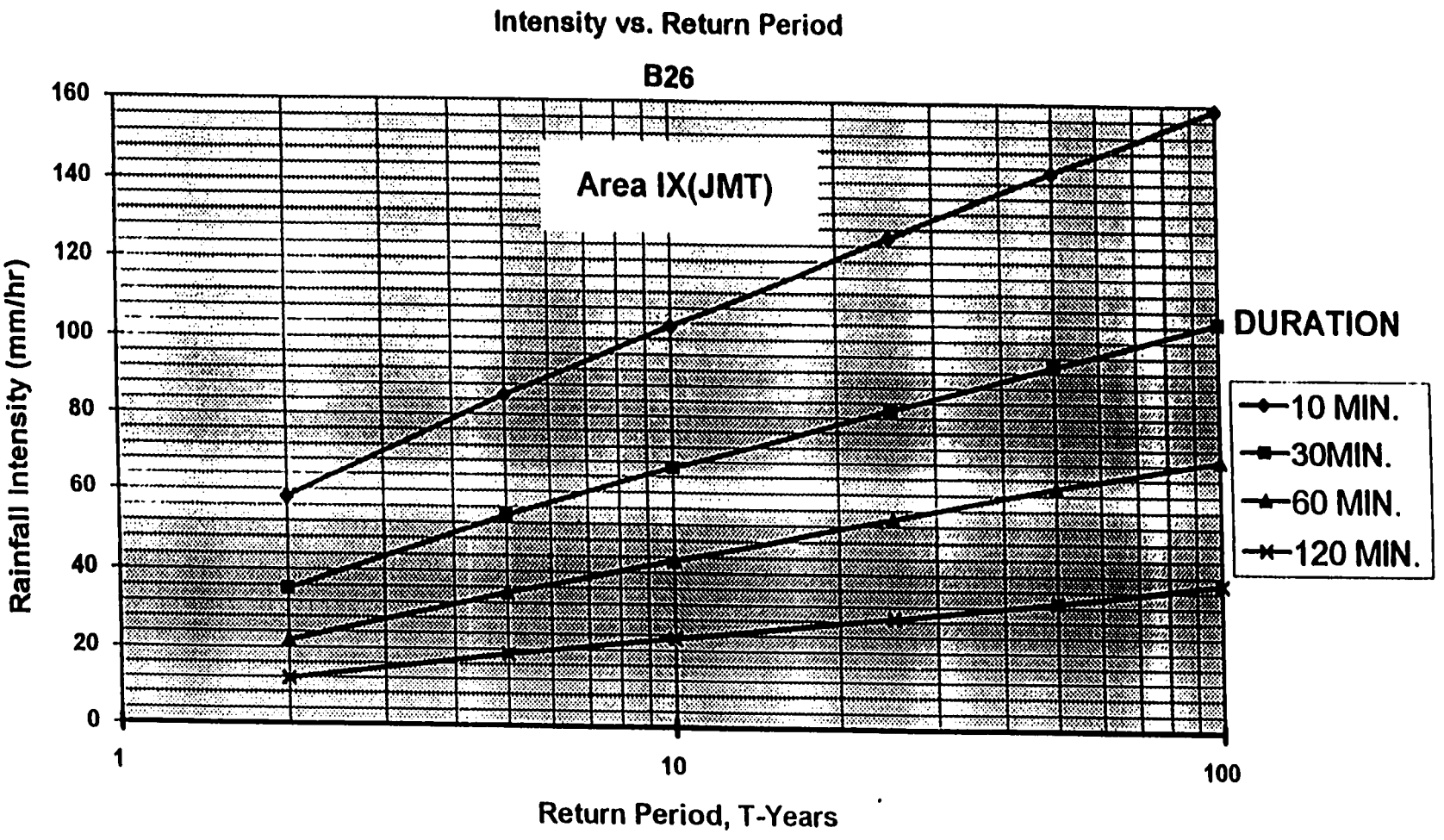
TAIF STATION



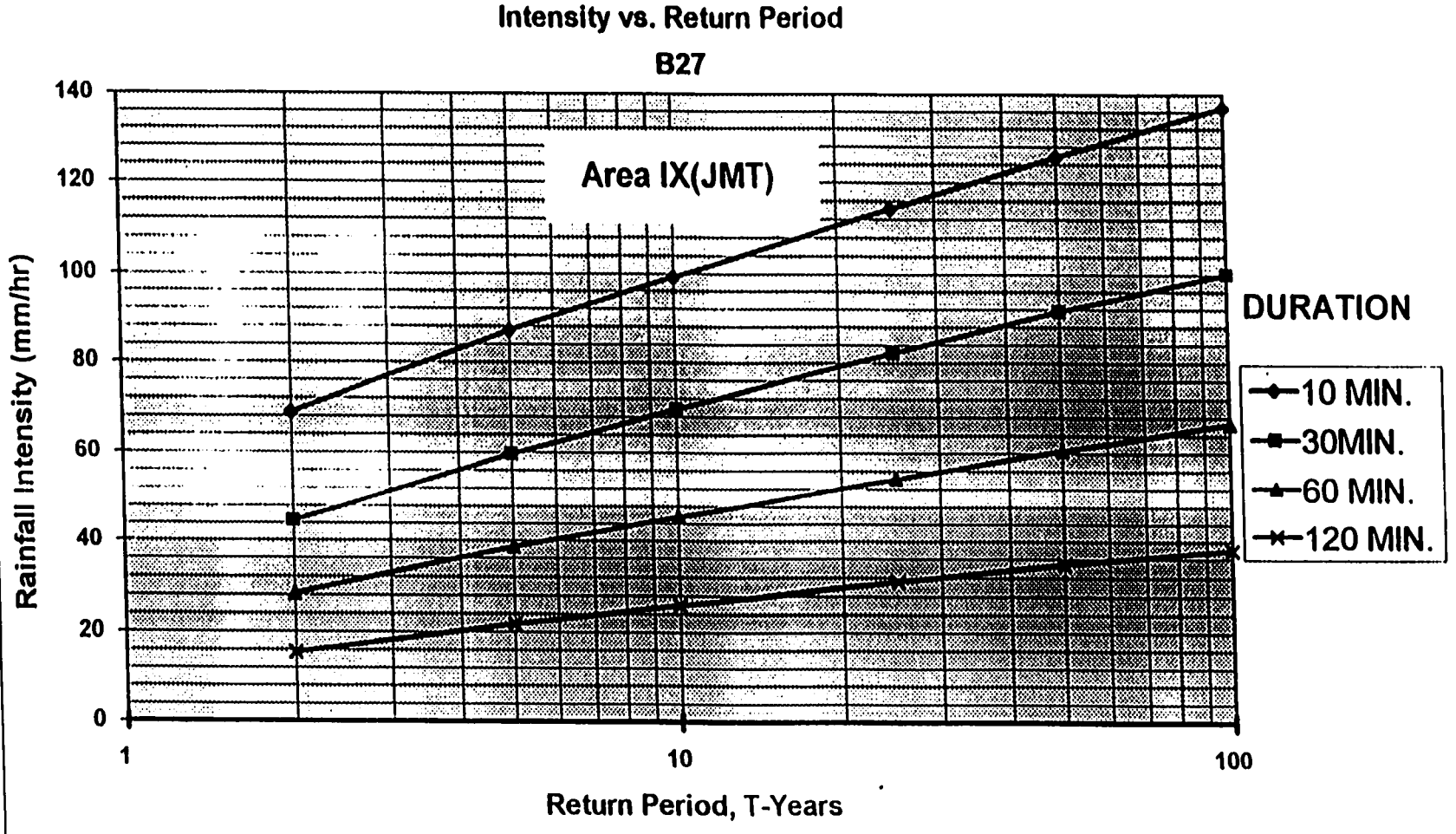
JERMUZ STATION



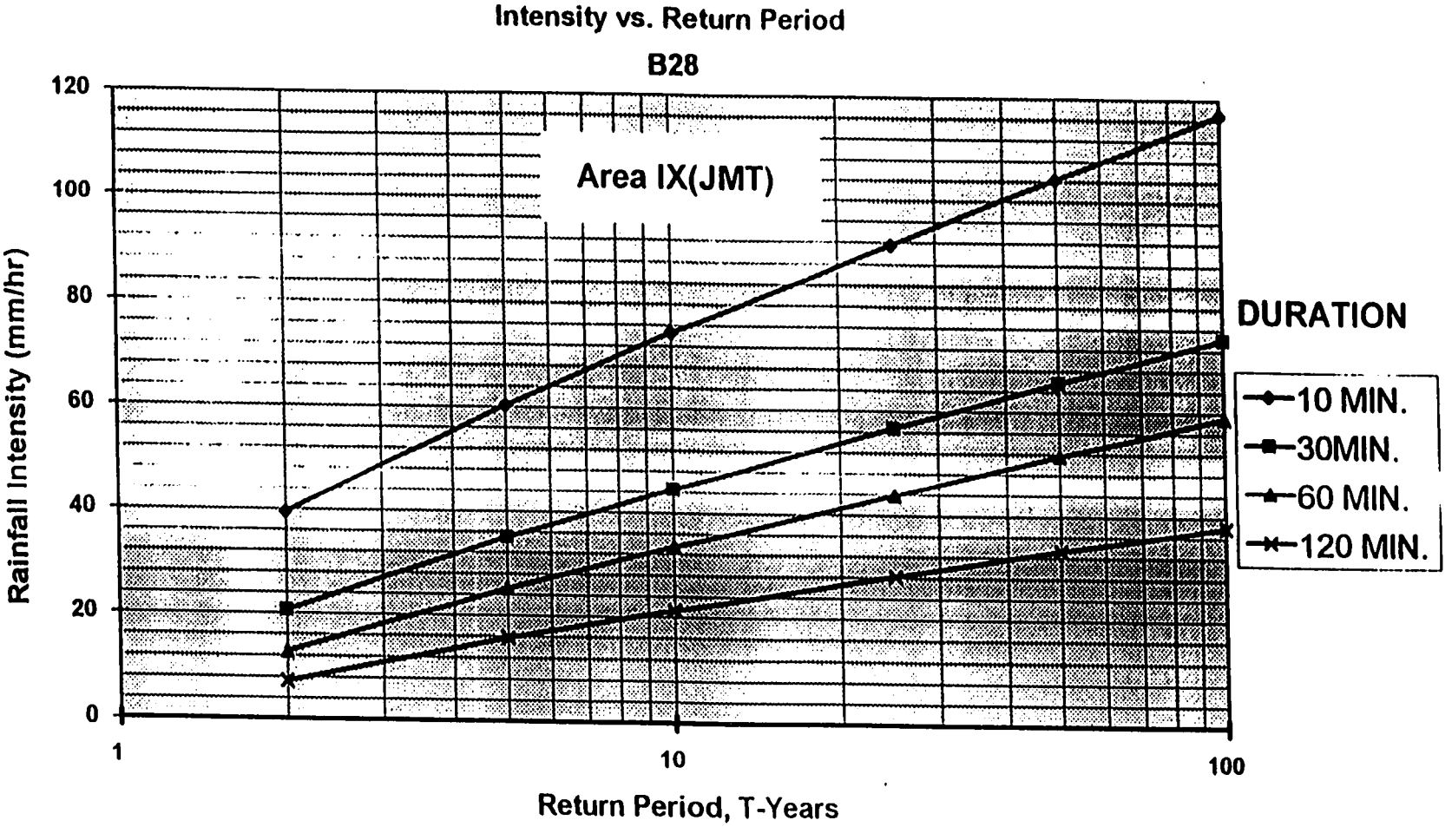
HEMA SAYSID STATION



WADI DAHIYAH STATION



AIN AZIZIAYH STATION



APPENDIX C

C_1 - C_7

$$\frac{P^t}{P^{60}}$$

t = 10 & 30 min.

T = 50, 25, 10, 5, and 2 Years

Ratios of Saudi Arabia Using Hershfield's Relations

(C-1)

STATION NAME: TABUK

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.764	0.855
25	0.749	0.856
10	0.721	0.88
5	0.684	0.859
2	0.67	0.865
Hershfield	0.45	0.79

STATION NAME: SAKKAKAH

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.639	0.693
25	0.622	0.659
10	0.586	0.64
5	0.537	0.591
2	0.36	0.412
Hershfield	0.45	0.79

STATION NAME: SULAYYIL

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.571	0.808
25	0.572	0.81
10	0.575	0.813
5	0.578	0.817
2	0.589	0.831
Hershfield	0.45	0.79

STATION NAME: NAJRAN

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.47	0.881
25	0.478	0.882
10	0.494	0.885
5	0.515	0.888
2	0.584	0.897
Hershfield	0.45	0.79

Ratios of Saudi Arabia Using Hershfield's Relations

(C-2)

STATION NAME: AL AIN QATAN

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.558	0.932
25	0.559	0.93
10	0.562	0.927
5	0.567	0.921
2	0.586	0.9
Hershfield	0.45	0.79

STATION NAME: SERAT ABIDA

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.475	0.784
25	0.478	0.787
10	0.484	0.792
5	0.492	0.799
2	0.515	0.821
Hershfield	0.45	0.79

STATION NAME: THAWILA

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.505	0.615
25	0.508	0.613
10	0.513	0.608
5	0.52	0.602
2	0.539	0.586
Hershfield	0.45	0.79

STATION NAME: ABU JINNAHA

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.282	0.737
25	0.295	0.741
10	0.319	0.763
5	0.356	0.767
2	0.515	0.833
Hershfield	0.45	0.79

Ratios of Saudi Arabia Using Hershfield's Relations
(C-3)

STATION NAME: ALSARRAR

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.735	0.784
25	0.726	0.786
10	0.779	0.791
5	0.689	0.796
2	0.634	0.81
Hershfield	0.45	0.79

STATION NAME: KHURAIS

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.497	0.774
25	0.501	0.777
10	0.508	0.782
5	0.518	0.789
2	0.552	0.813
Hershfield	0.45	0.79

STATION NAME: AL KHARJ

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.611	0.842
25	0.611	0.843
10	0.61	0.846
5	0.61	0.85
2	0.608	0.864
Hershfield	0.45	0.79

STATION NAME: RIYADAH

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.565	0.81
25	0.56	0.809
10	0.549	0.806
5	0.535	0.803
2	0.49	0.791
Hershfield	0.45	0.79

Ratios of Saudi Arabia Using Hershfield's Relations

(C-4)

STATION NAME: SUWAYDRH

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.502	0.911
25	0.503	0.909
10	0.506	0.904
5	0.51	0.933
2	0.524	0.872
Hershfield	0.45	0.79

STATION NAME: KWASH

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.631	0.748
25	0.612	0.752
10	0.578	0.759
5	0.541	0.767
2	0.45	0.787
Hershfield	0.45	0.79

STATION NAME: AL MEDINA FARM

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.577	0.794
25	0.575	0.794
10	0.571	0.795
5	0.566	0.795
2	0.547	0.797
Hershfield	0.45	0.79

STATION NAME: KUBAH

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.414	0.787
25	0.417	0.79
10	0.422	0.795
5	0.428	0.802
2	0.446	0.823
Hershfield	0.45	0.79

Ratios of Saudi Arabia Using Hershfield's Relations
(C-5)

STATION NAME: HEMA SAYSID

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.386	0.757
25	0.39	0.761
10	0.4	0.769
5	0.41	0.779
2	0.444	0.808
Hershfield	0.45	0.77

STATION NAME: WADI DAHYYAH

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.346	0.755
25	0.352	0.758
10	0.363	0.765
5	0.376	0.772
2	0.406	0.789
Hershfield	0.45	0.79

STATION NAME: JERMUZ

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.436	0.757
25	0.441	0.763
10	0.452	0.773
5	0.465	0.785
2	0.504	0.823
Hershfield	0.45	0.79

STATION NAME: AIN AZIZIYAH

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.337	0.636
25	0.348	0.646
10	0.369	0.667
5	0.399	0.696
2	0.519	0.809
Hershfield	0.45	0.79

Ratios of Saudi Arabia Using Hershfield's Relations
(C-6)

STATION NAME: BISHAH

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.516	0.8665
25	0.517	0.868
10	0.519	0.872
5	0.522	0.877
2	0.544	0.911
Hershfield	0.45	0.79

STATION NAME: YABRIN

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.69	0.884
25	0.681	0.878
10	0.664	0.867
5	0.642	0.852
2	0.572	0.806
Hershfield	0.45	0.79

STATION NAME: AIN NIMAS

RETURN PERIOD YEARS	10 MIN	30 MIN
50	0.535	0.572
25	0.528	0.571
10	0.514	0.569
5	0.5	0.566
2	0.457	0.559
Hershfield	0.45	0.79

STATION NAME: HARADH

RETURN PERIOD YEARS	10 MIN	30 MIN
50	0.454	0.833
25	0.456	0.83
10	0.459	0.823
5	0.464	0.815
2	0.479	0.79
Hershfield	0.45	0.79

Ratios of Saudi Arabia Using Hershfield's Relations

(C-7)

STATION NAME: KIYAT

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.344	0.7
25	0.351	0.706
10	0.365	0.721
5	0.385	0.741
2	0.274	0.822
Hershfield	0.45	0.79

STATION NAME: MURAYR

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.72	0.915
25	0.713	0.91
10	0.698	0.899
5	0.678	0.885
2	0.6	0.825
Hershfield	0.45	0.79

STATION NAME: HANAKIYAH

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.489	0.862
25	0.492	0.86
10	0.499	0.855
5	0.51	0.847
2	0.561	0.812
Hershfield	0.45	0.79

STATION NAME: TAIF

RETURN PERIOD YEARS	10 MIN.	30 MIN.
50	0.448	0.8
25	0.445	0.796
10	0.441	0.789
5	0.455	0.78
2	0.42	0.754
Hershfield	0.45	0.79

APPENDIX D

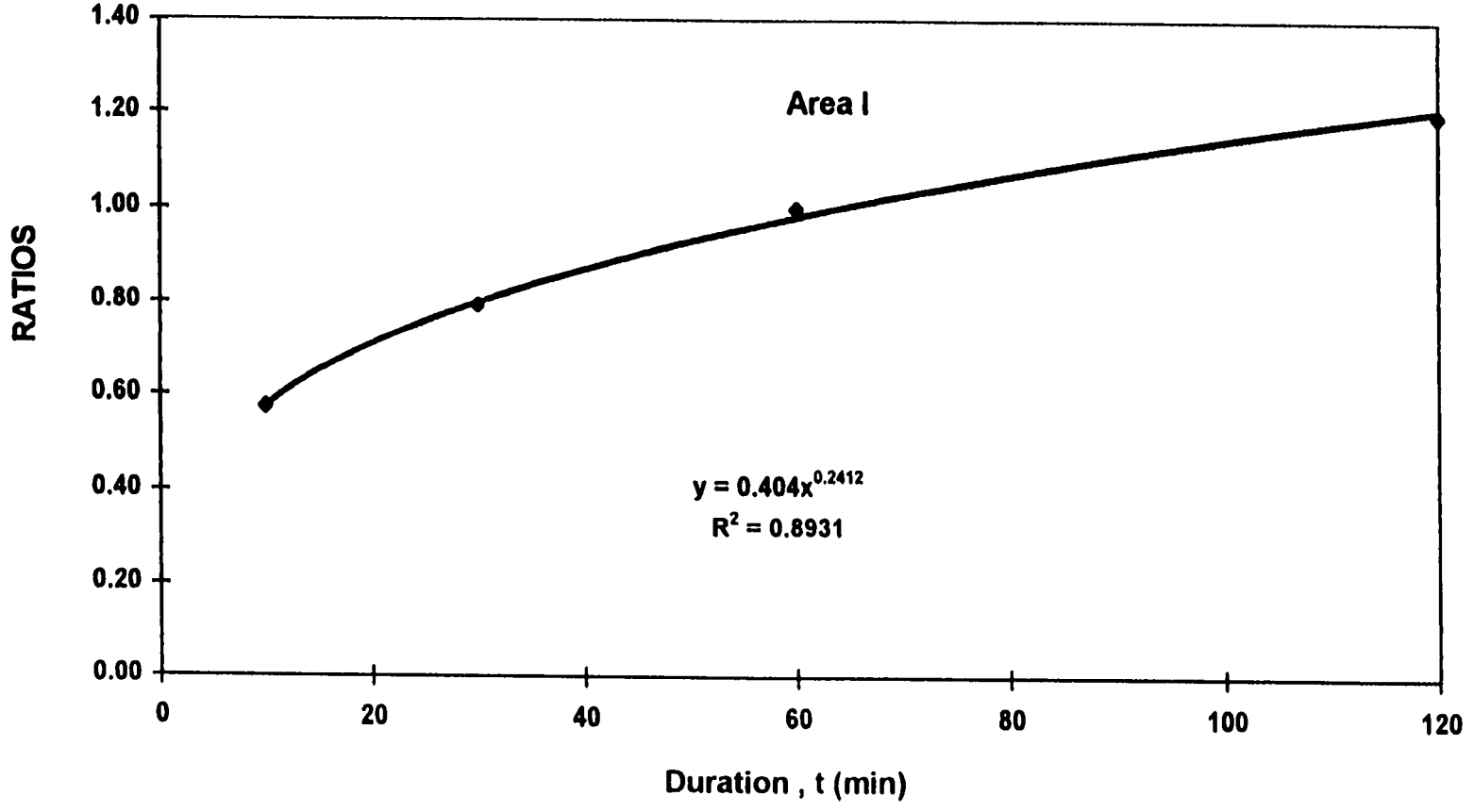
D_1 - D_{28}

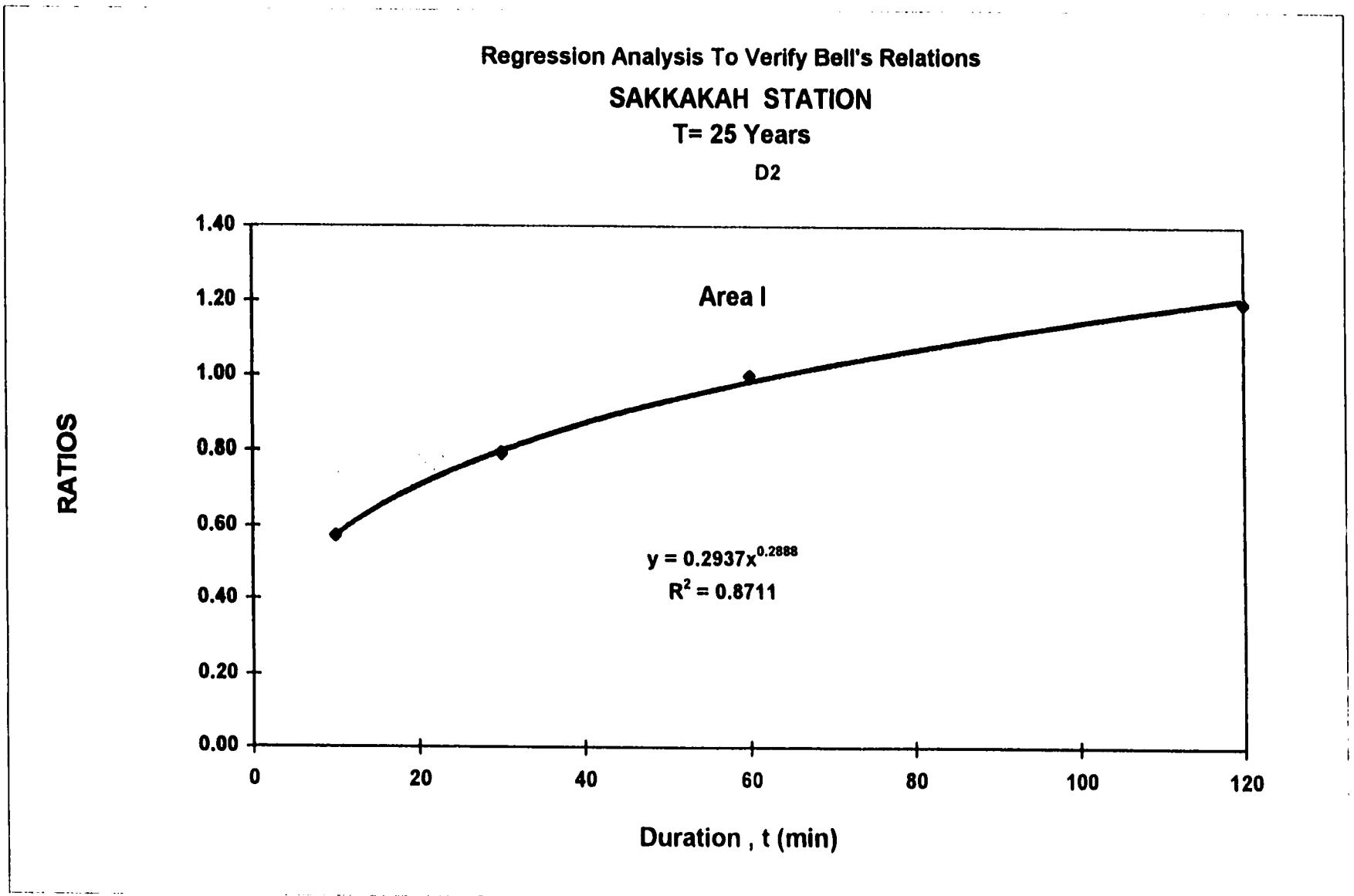
$$\frac{P_T^t}{P_T^{60}}$$

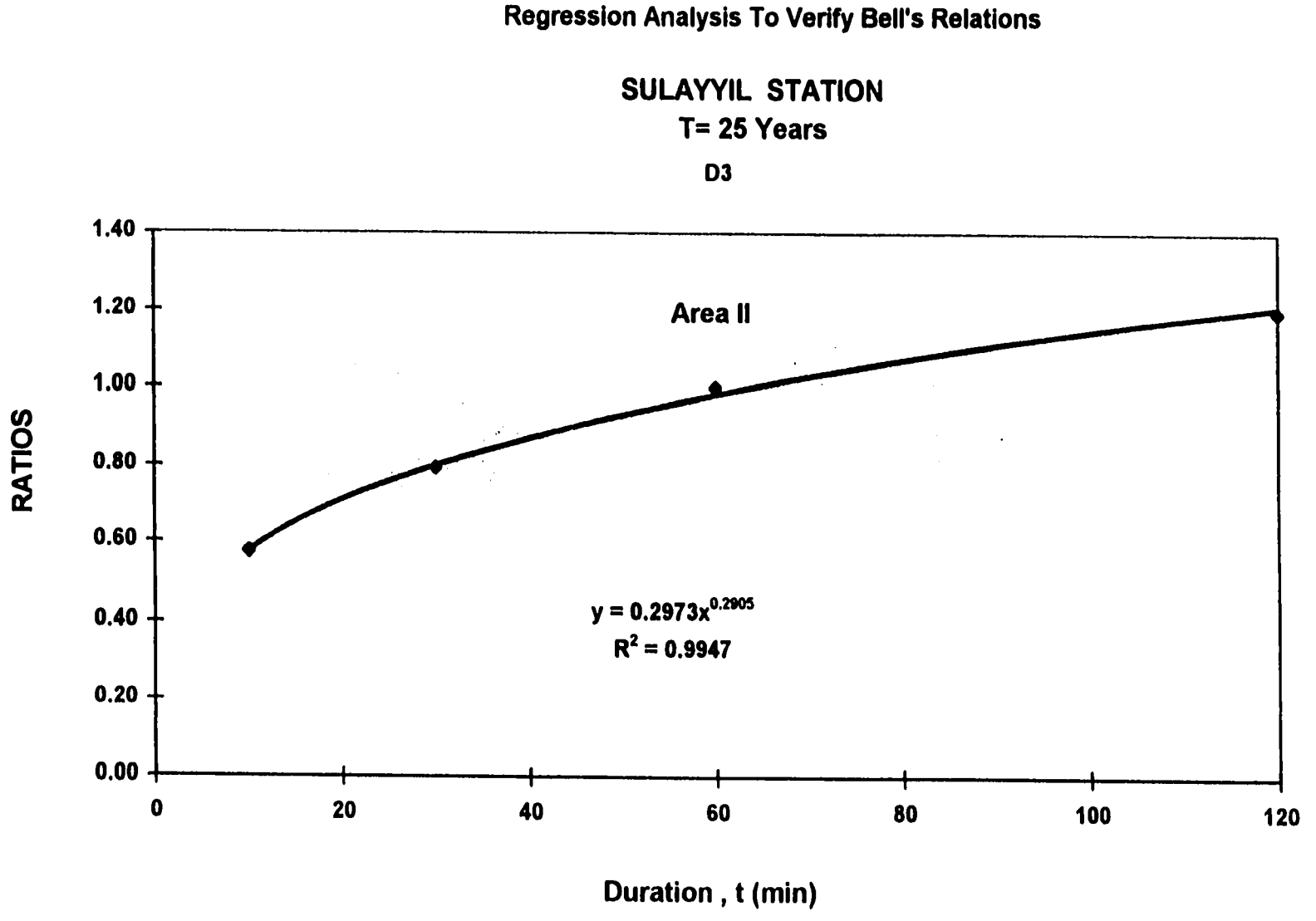
Model Curves

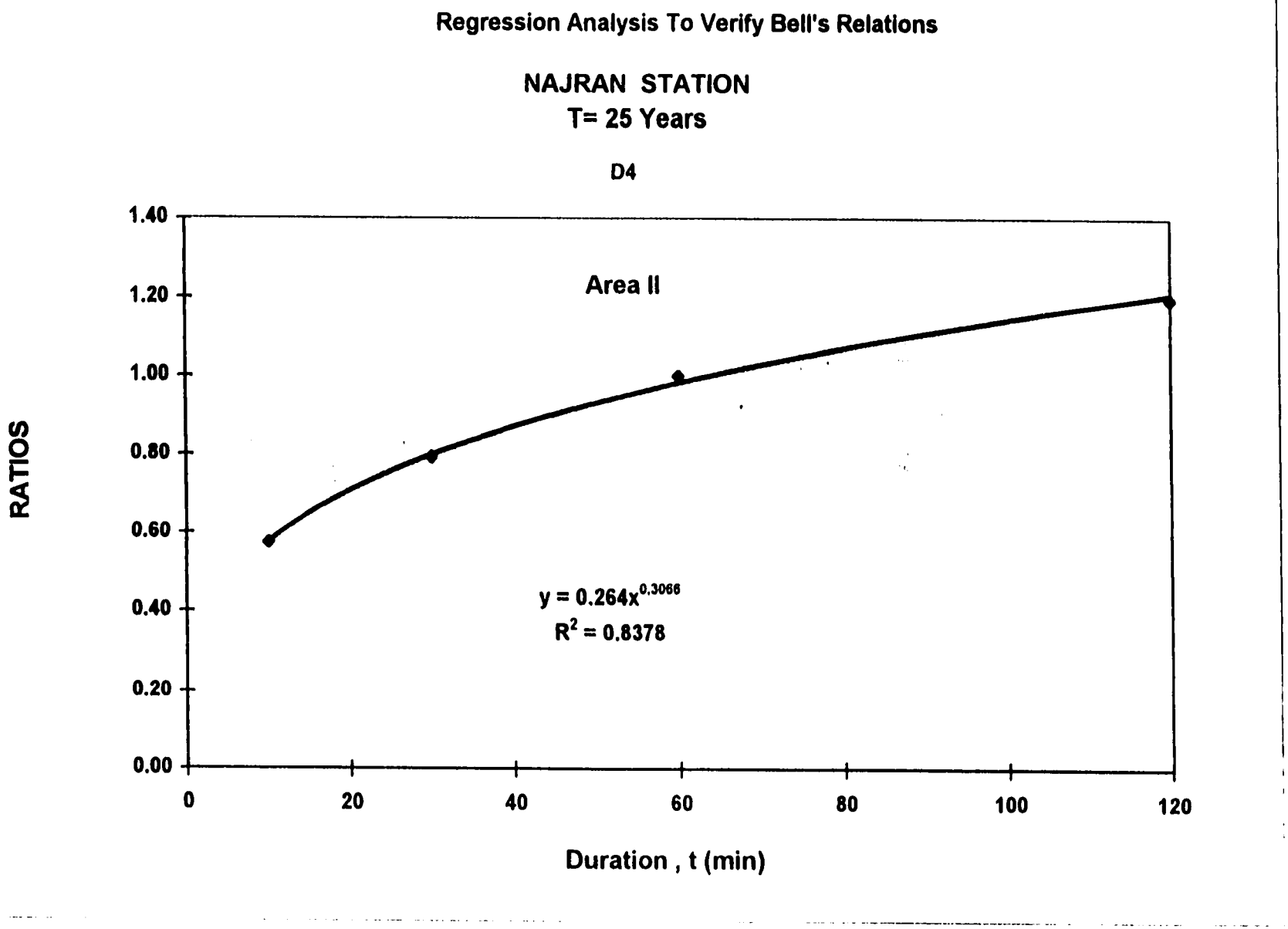
Regression Analysis To Verify Bell's Relations

TABUK STATION
T= 25 Years
D1



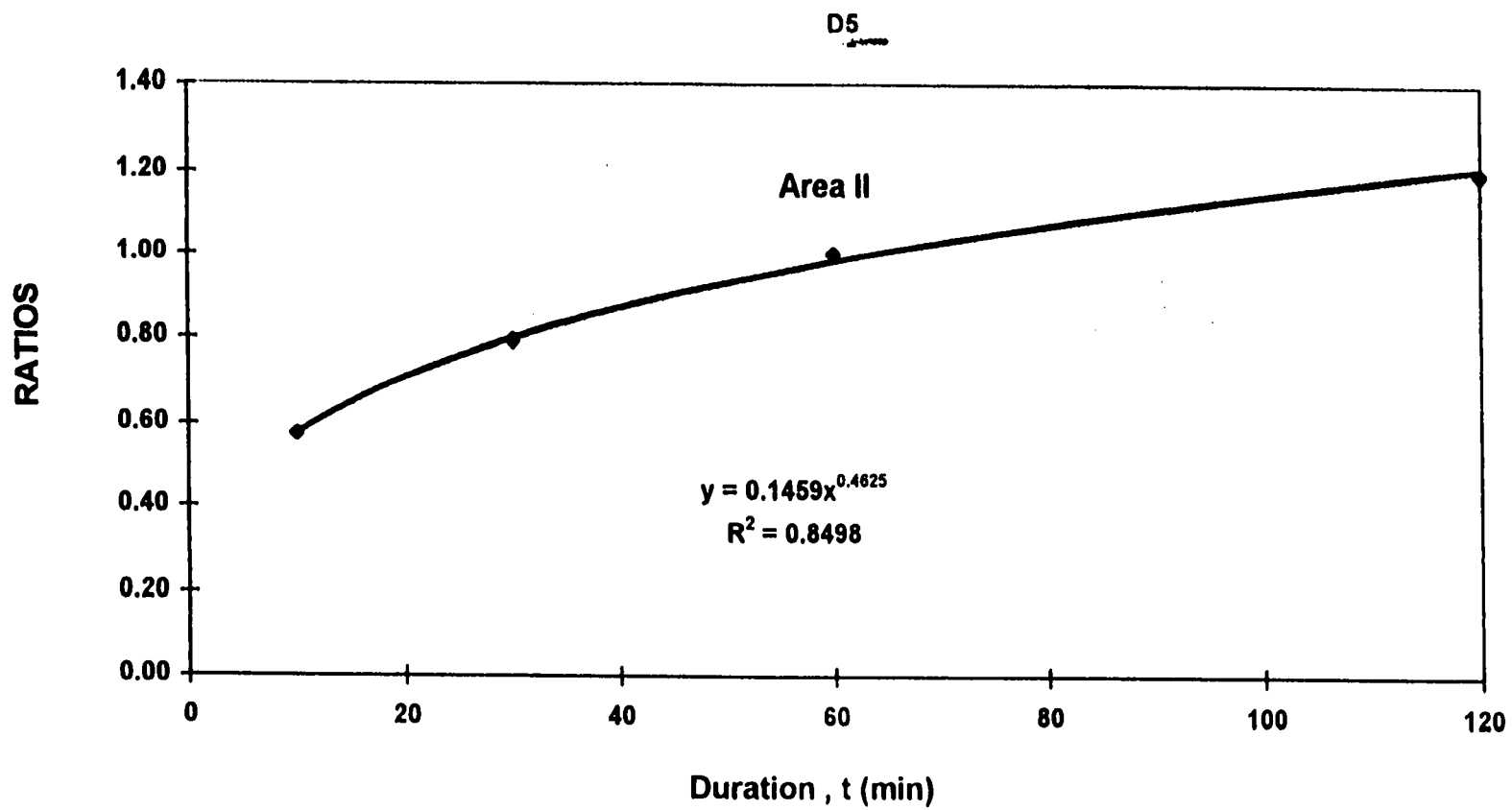

Regression Analysis To Verify Bell's Relations
SAKKAKAH STATION
T= 25 Years
D2
RATIOS
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Area I
y = 0.2937x^0.2888
R² = 0.8711
0
20
40
60
80
100
120
Duration , t (min)

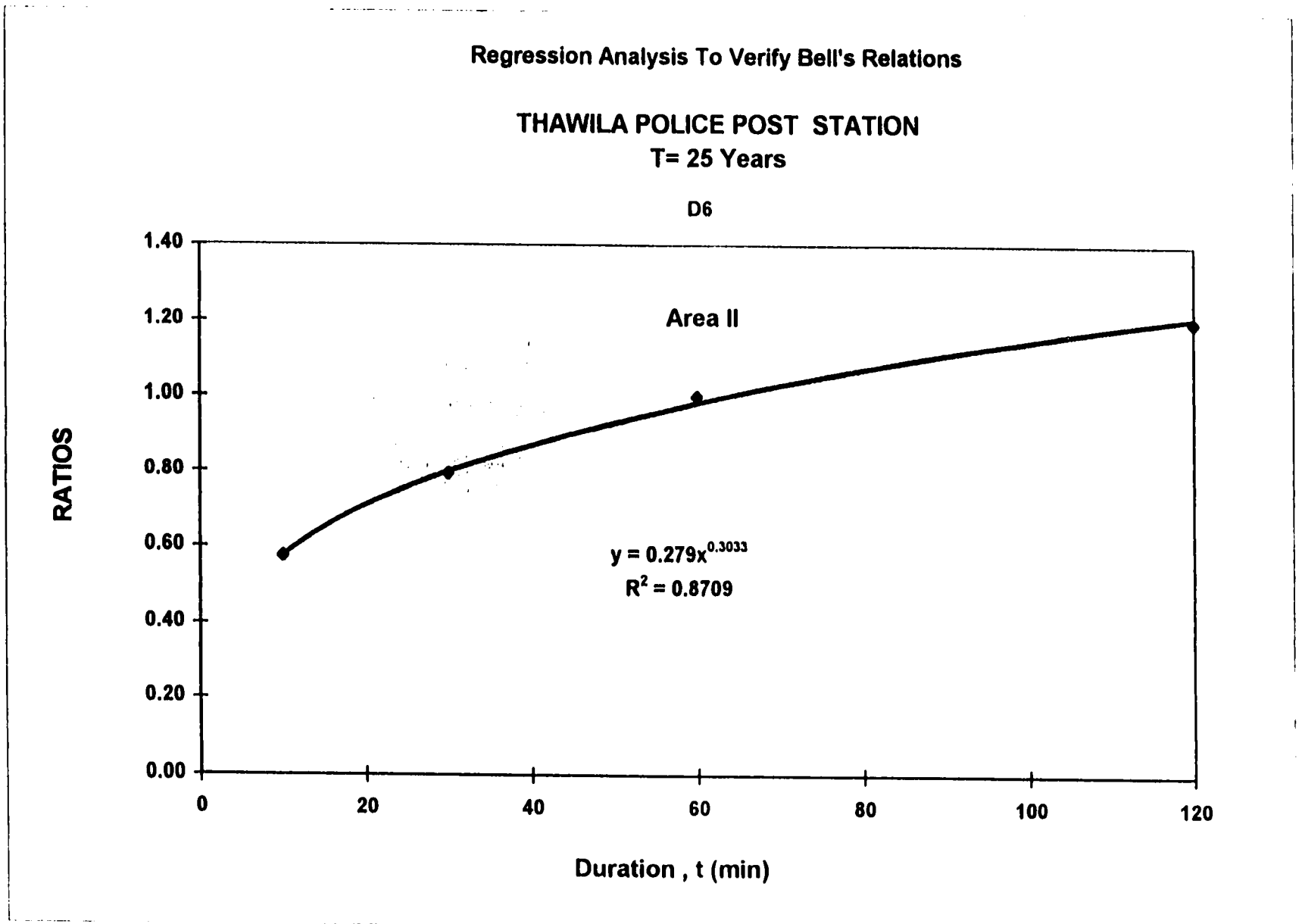

Regression Analysis To Verify Bell's Relations
SULAYYIL STATION
T= 25 Years
D3
RATIOS
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Area II
y = 0.2973x^0.2905
R^2 = 0.9947
0
20
40
60
80
100
120
Duration , t (min)


Regression Analysis To Verify Bell's Relations
NAJRAN STATION
T= 25 Years
D4
Area II
y = 0.264x^0.3066
R^2 = 0.8378
RATIOS
Duration , t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120

Regression Analysis To Verify Bell's Relations

AL AIN QATAN STATION
T= 25 Years

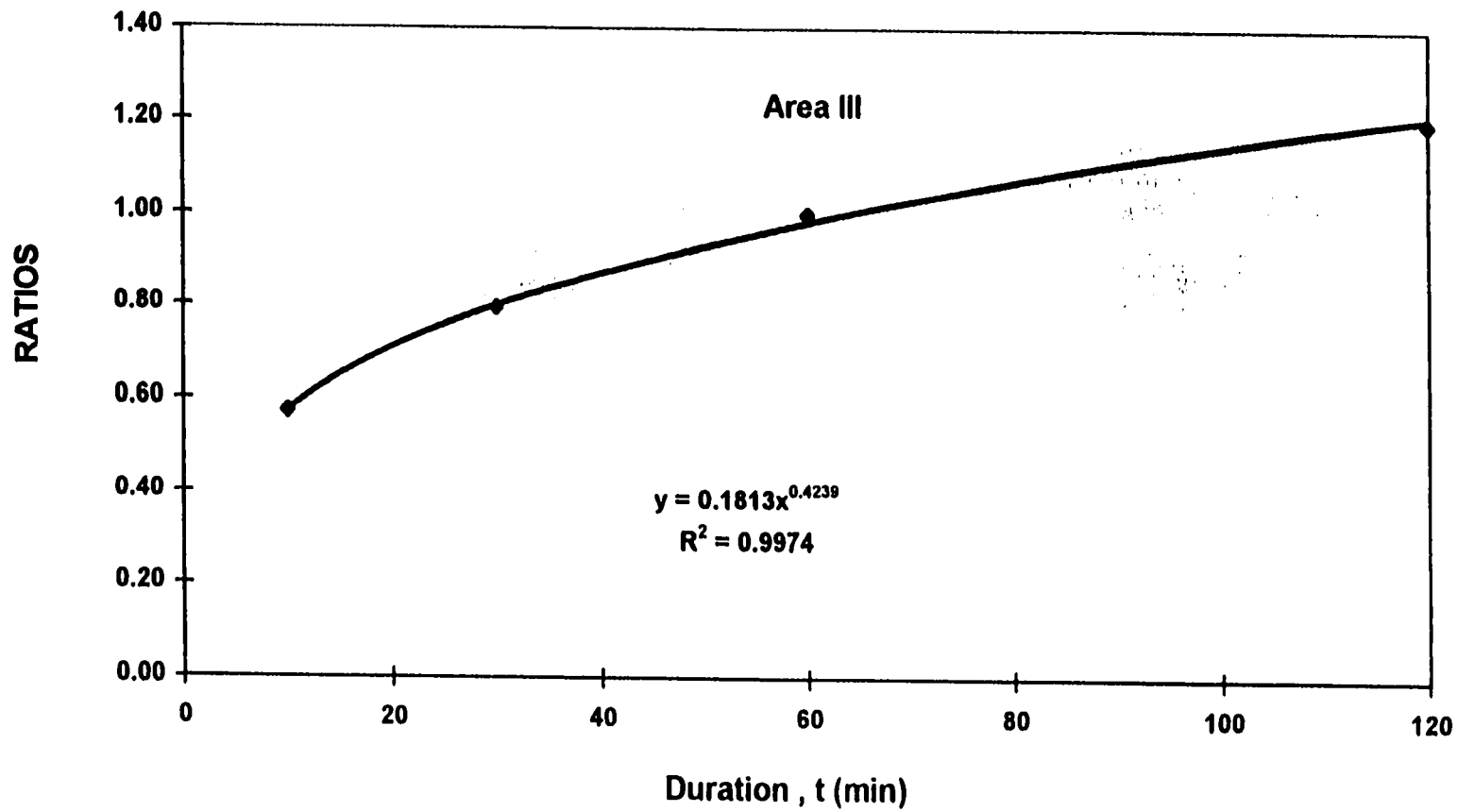



Regression Analysis To Verify Bell's Relations
THAWILA POLICE POST STATION
T= 25 Years
D6
Area II
y = 0.279x^0.3033
R^2 = 0.8709
RATIOS
Duration , t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120

Regression Analysis To Verify Bell's Relations

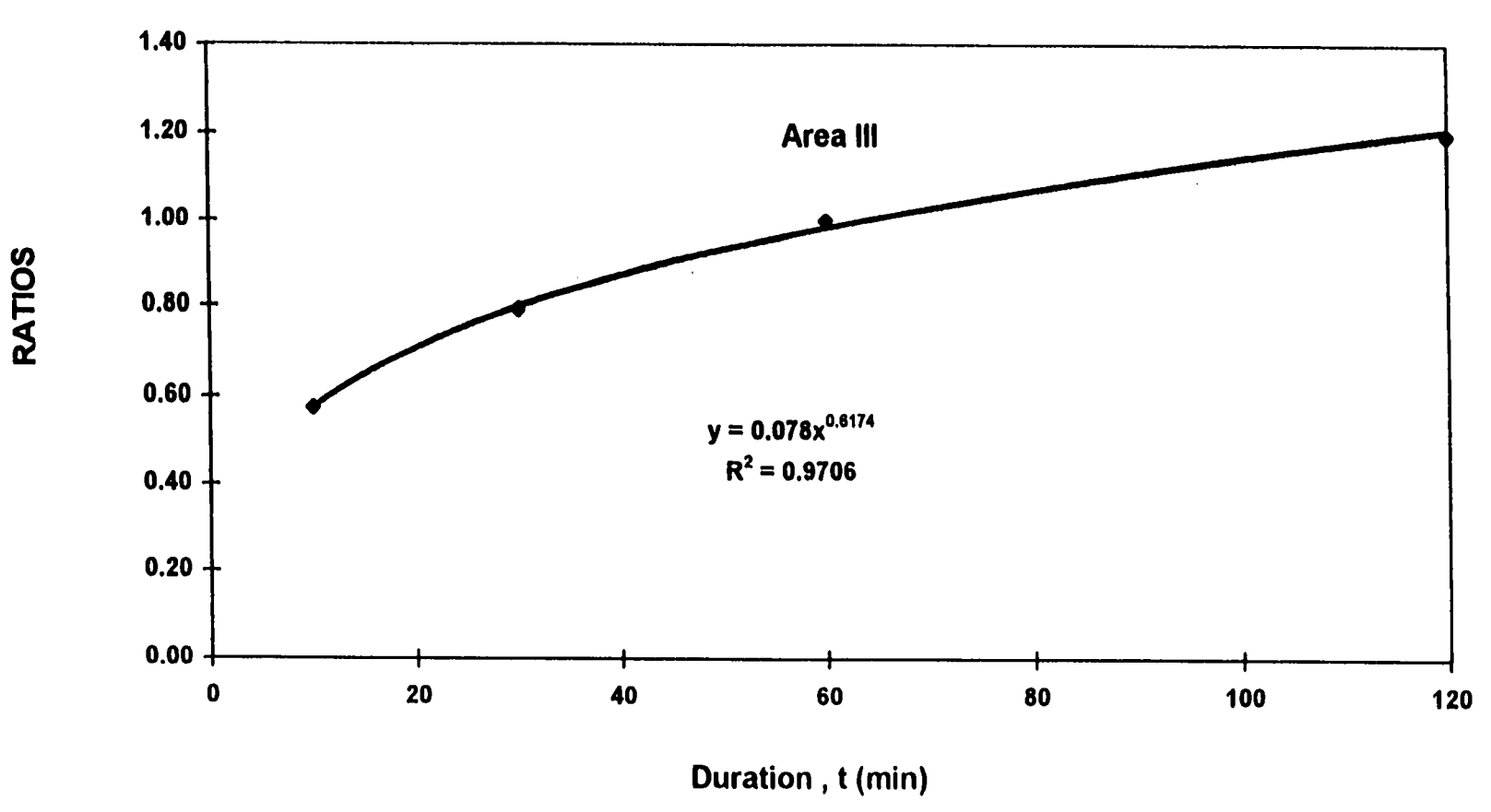
SERAT ABIDA STATION
T= 25 Years

D7



Regression Analysis To Verify Bell's Relations

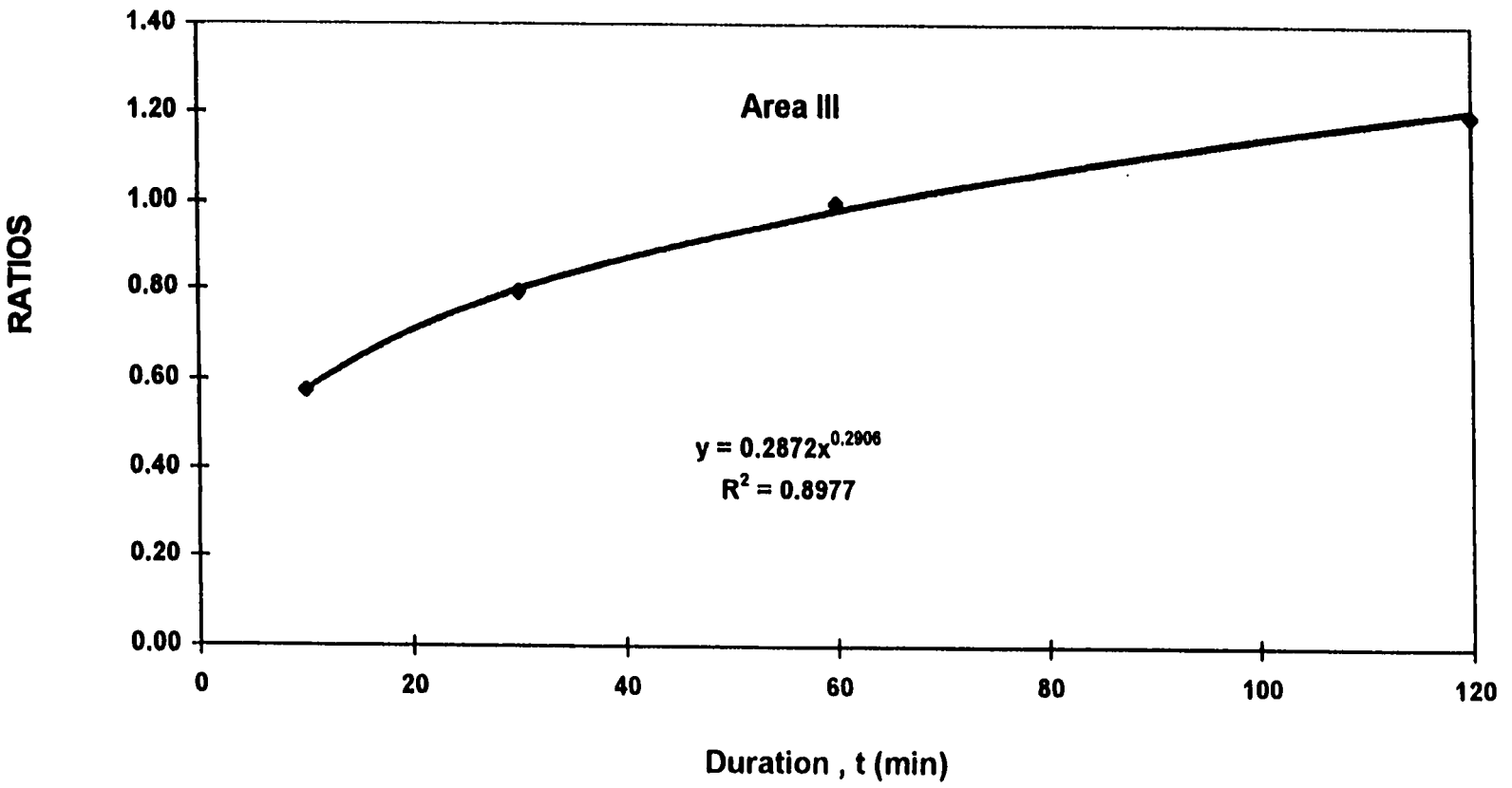
ABU JINNAHA STATION
T= 25 Years

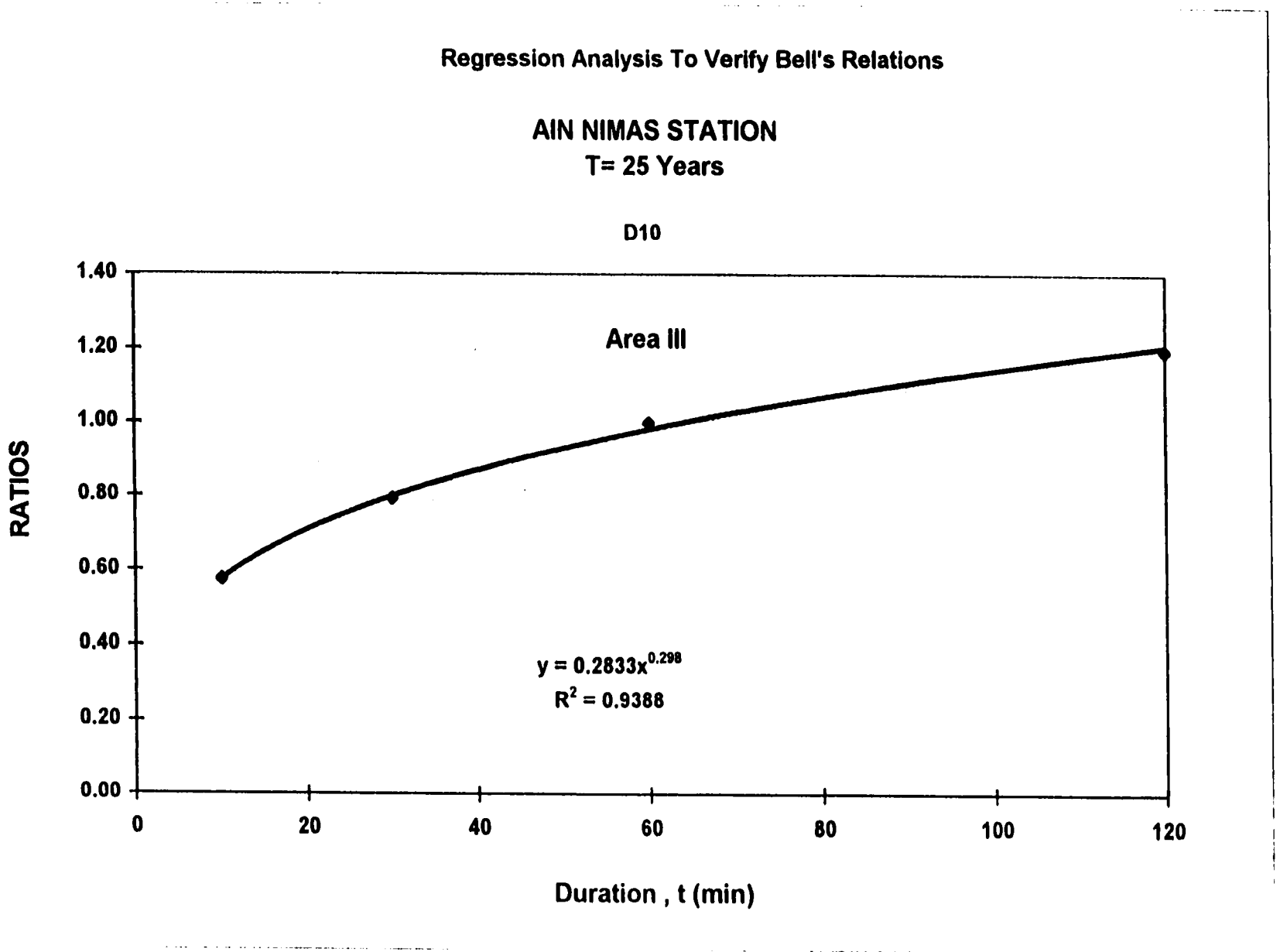


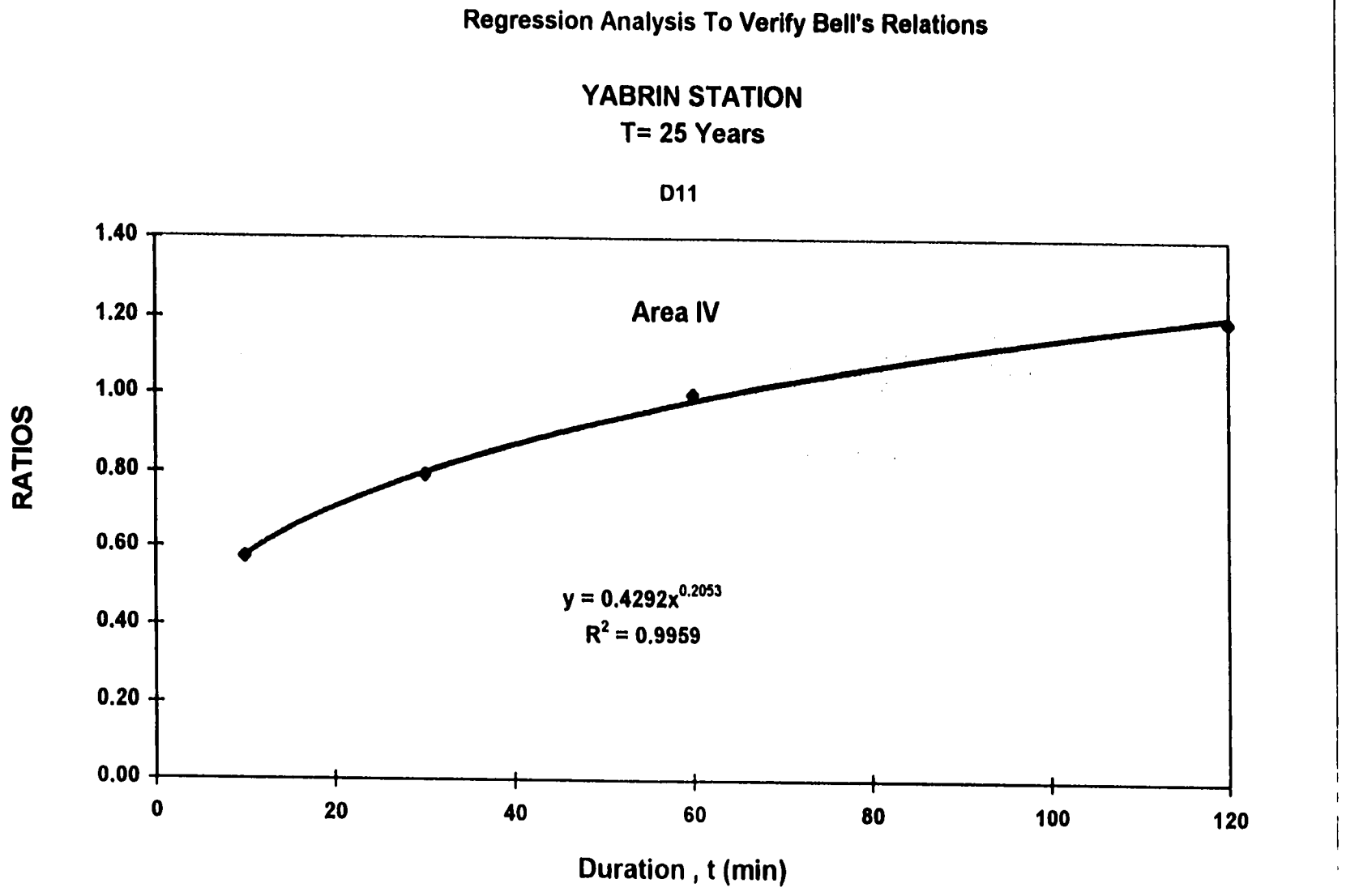
Regression Analysis To Verify Bell's Relations

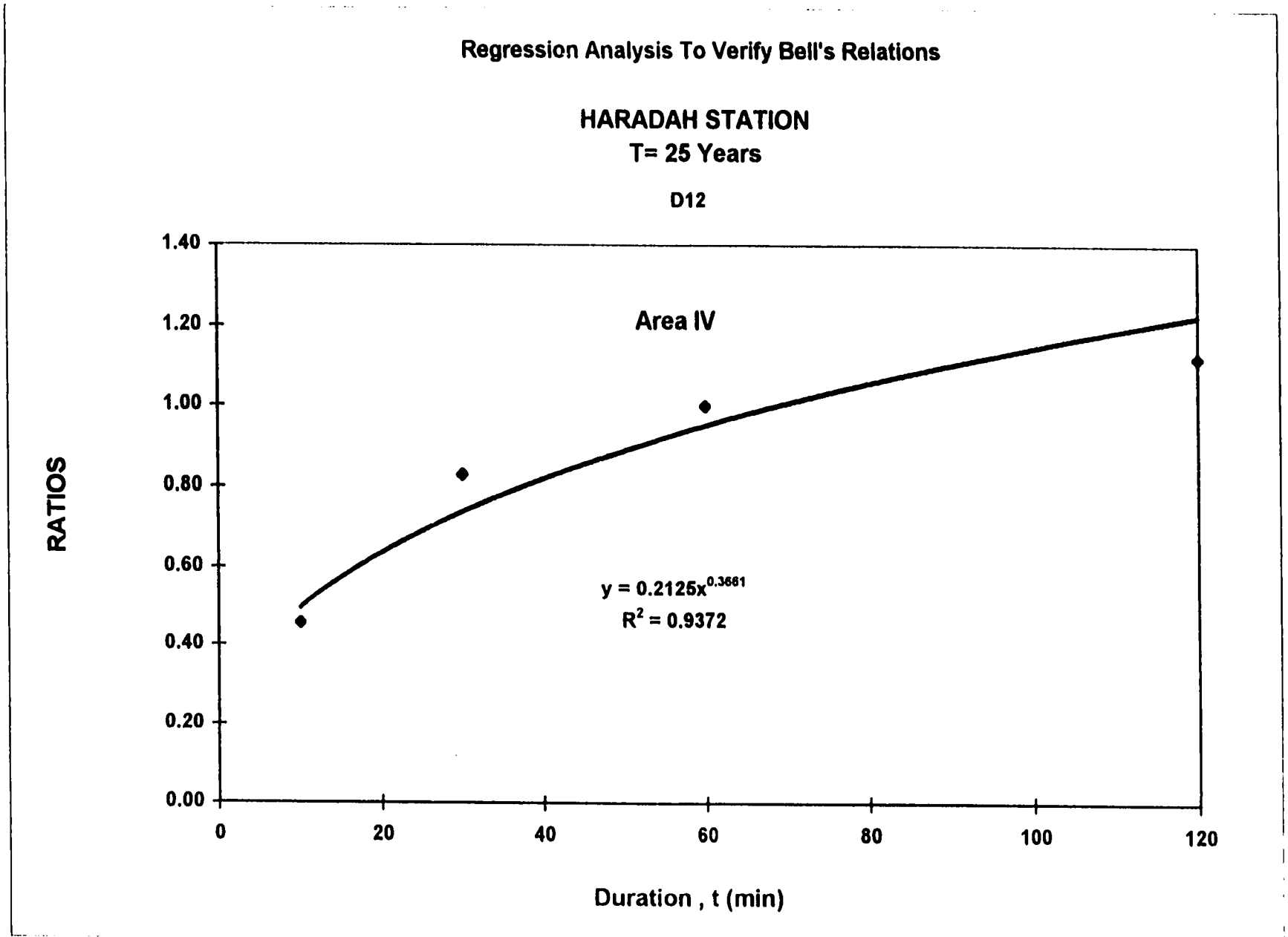
BISHAH STATION
T= 25 Years

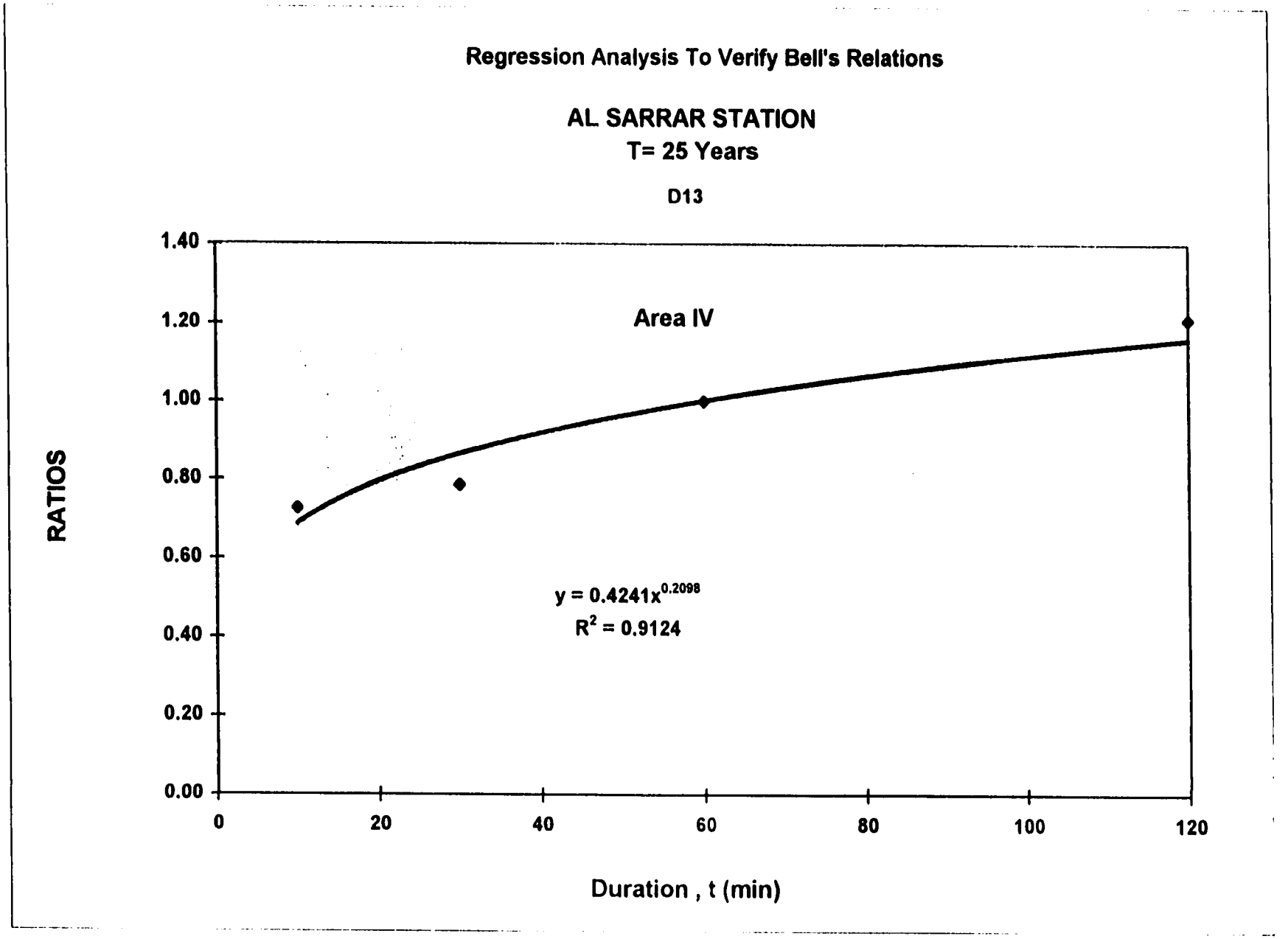
D9

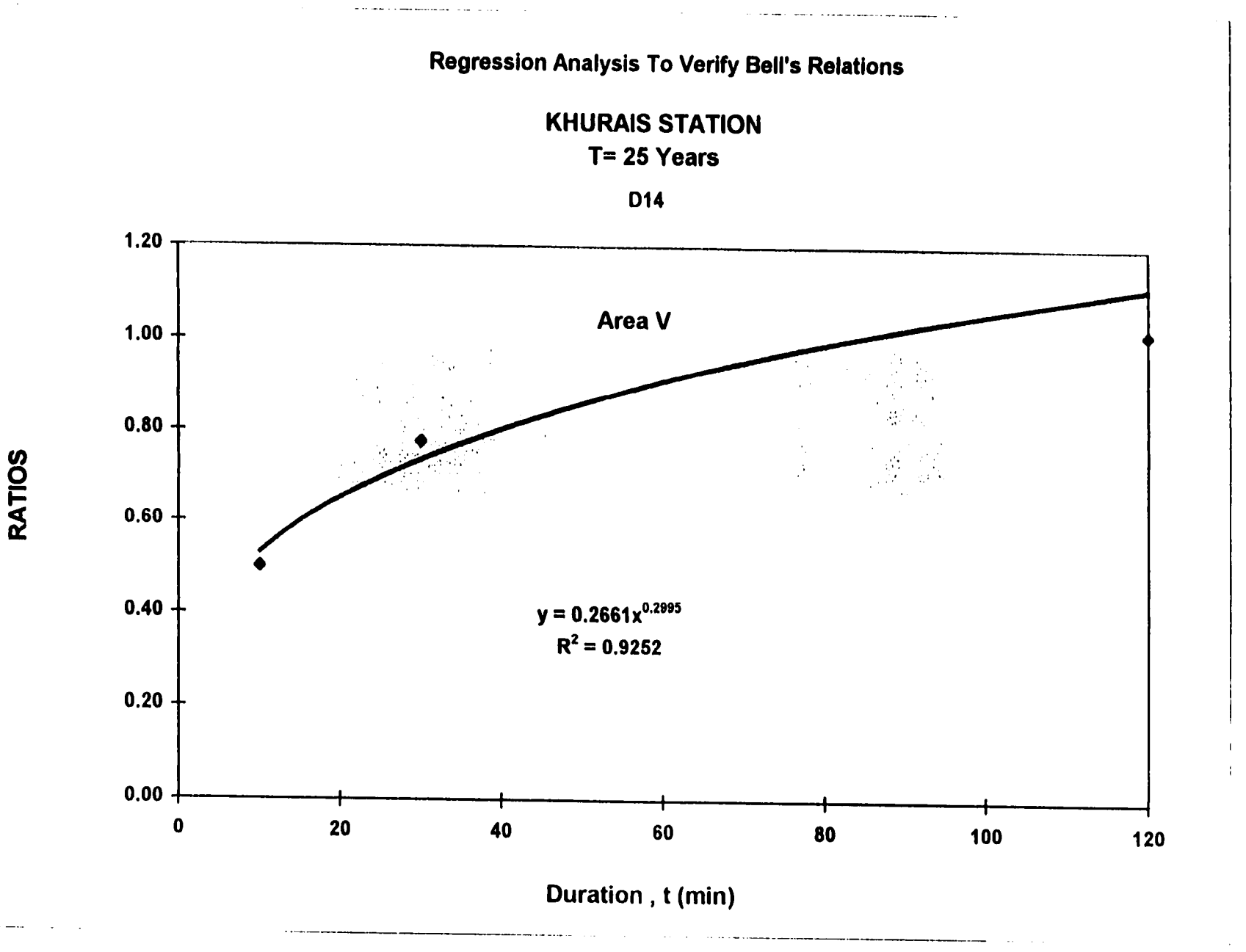


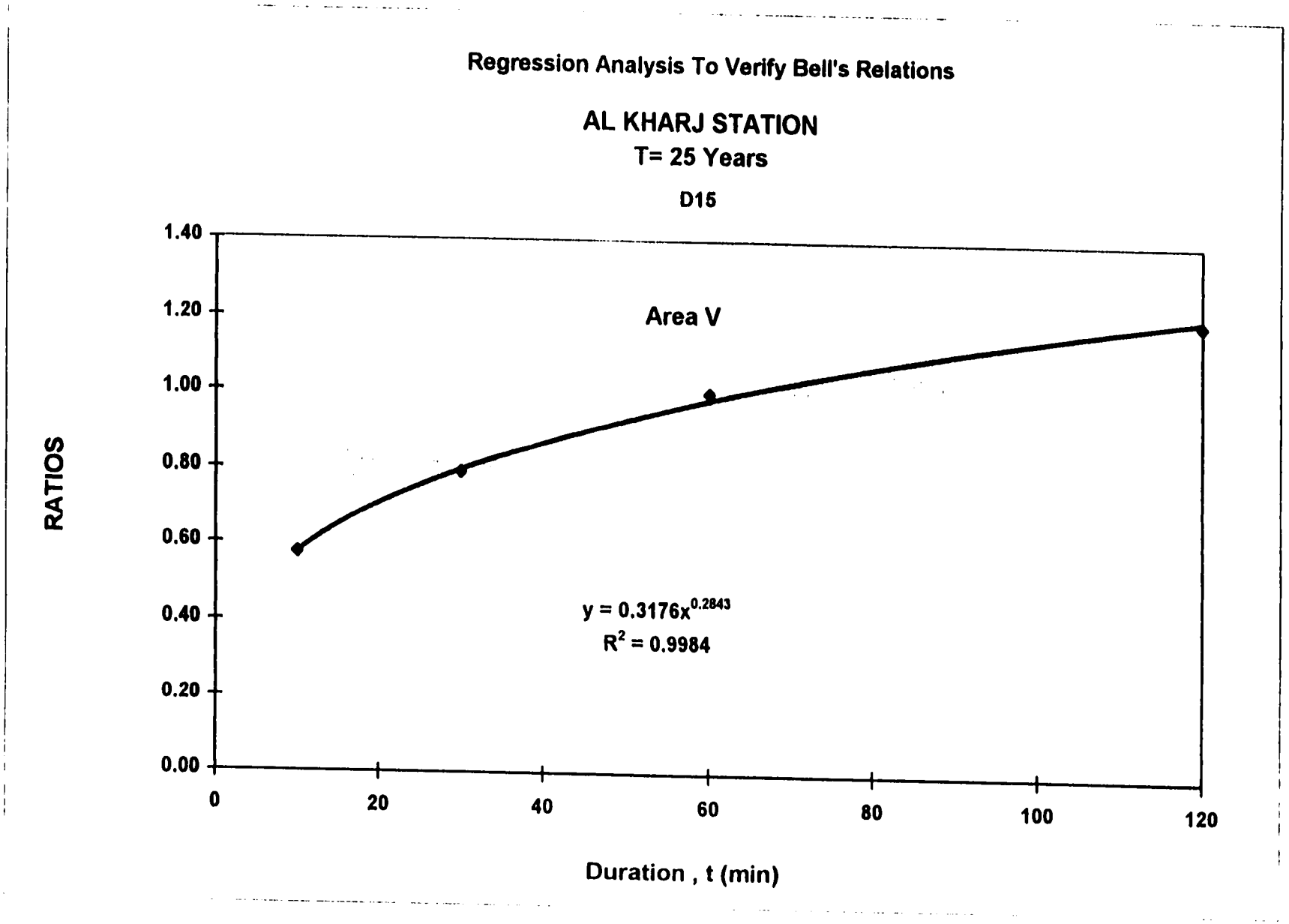

Regression Analysis To Verify Bell's Relations
AIN NIMAS STATION
T= 25 Years
D10
Area III
y = 0.2833x^0.298
R^2 = 0.9388
RATIOS
Duration , t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Bell's Relations
YABRIN STATION
T= 25 Years
D11
Area IV
y = 0.4292x^0.2053
R^2 = 0.9959
RATIOS
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120
Duration , t (min)


Regression Analysis To Verify Bell's Relations
HARADAH STATION
T= 25 Years
D12
Area IV
y = 0.2125x^0.3661
R^2 = 0.9372
RATIOS
Duration , t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Bell's Relations
AL SARRAR STATION
T= 25 Years
D13
Area IV
y = 0.4241x^0.2098
R^2 = 0.9124
RATIOS
Duration , t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120

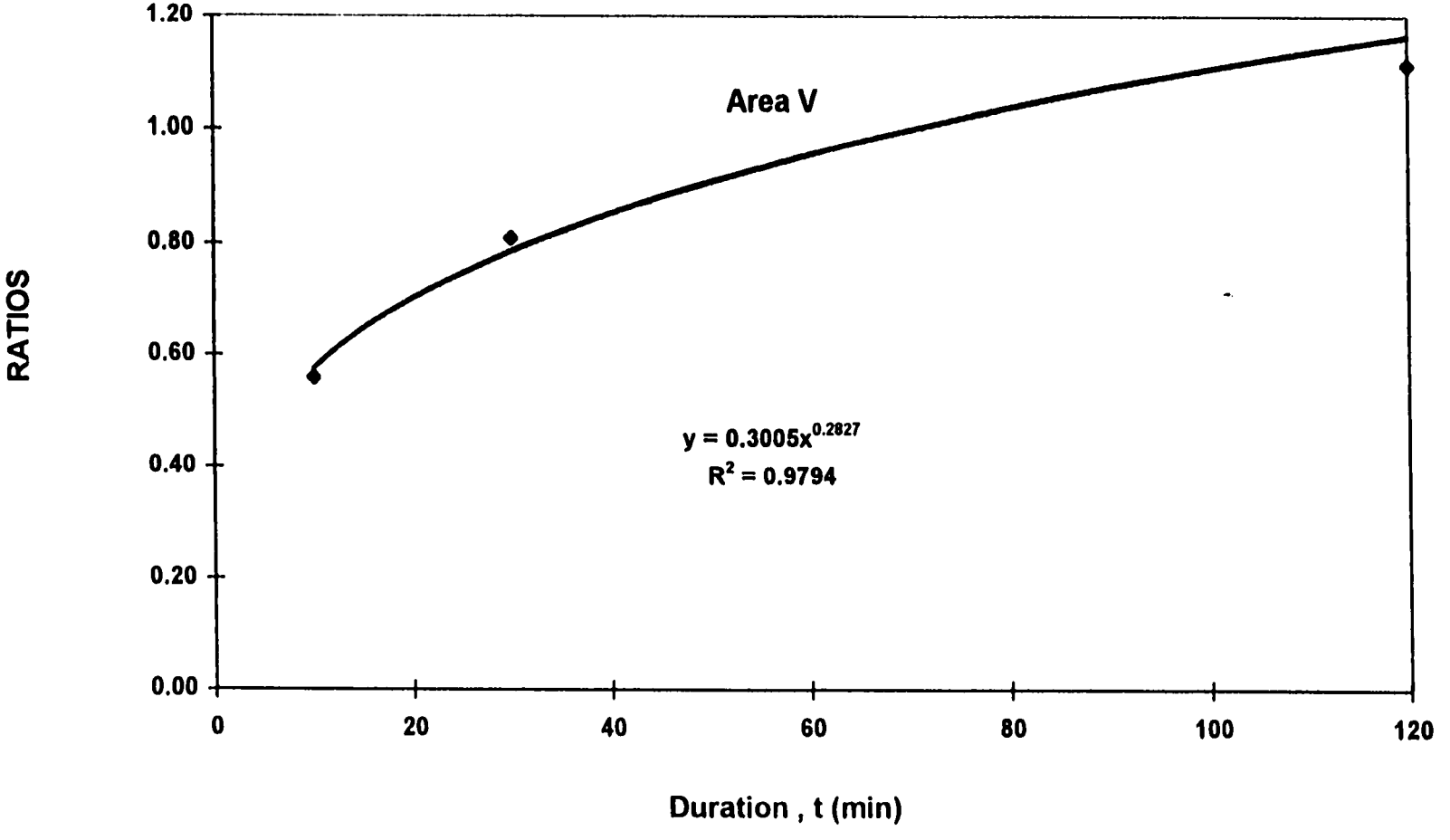

Regression Analysis To Verify Bell's Relations
KHURAIS STATION
T= 25 Years
D14
Area V
y = 0.2661x^0.2995
R² = 0.9252
RATIOS
Duration , t (min)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Bell's Relations
AL KHARJ STATION
T= 25 Years
D15
Area V
y = 0.3176x^0.2843
R^2 = 0.9984
RATIOS
Duration , t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120

Regression Analysis To Verify Bell's Relations

RIYADAH STATION
T= 25 Years

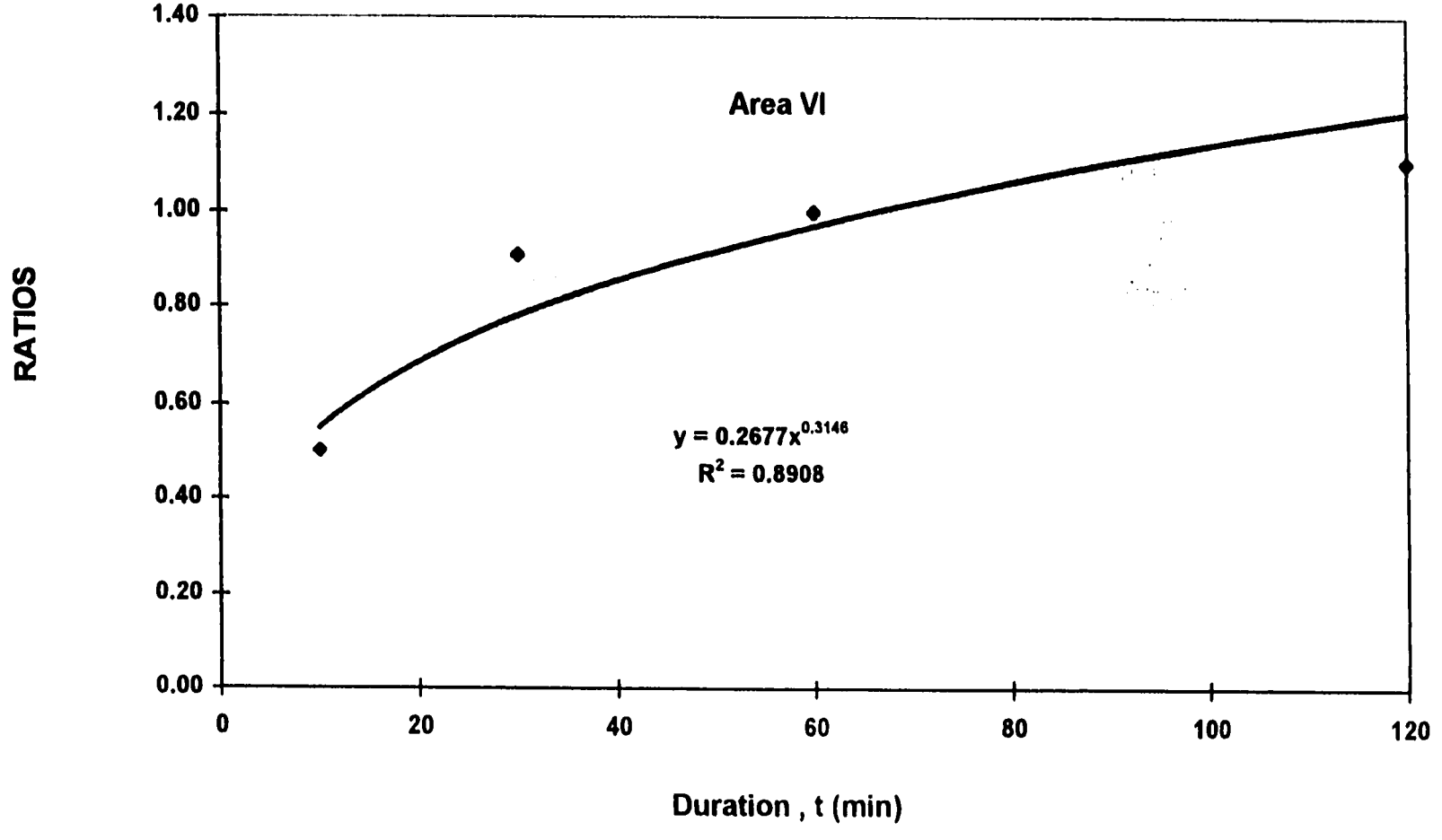
D16

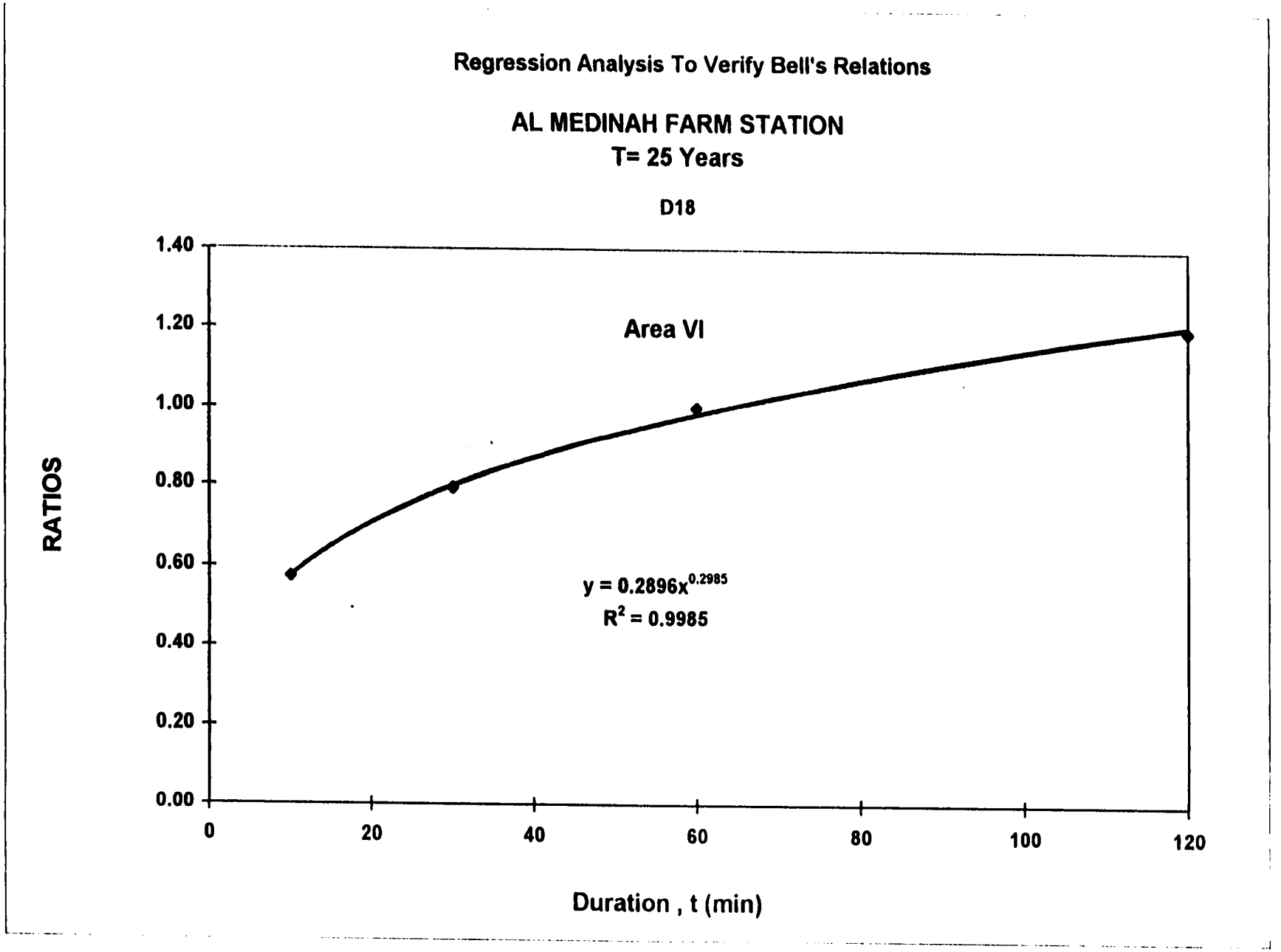


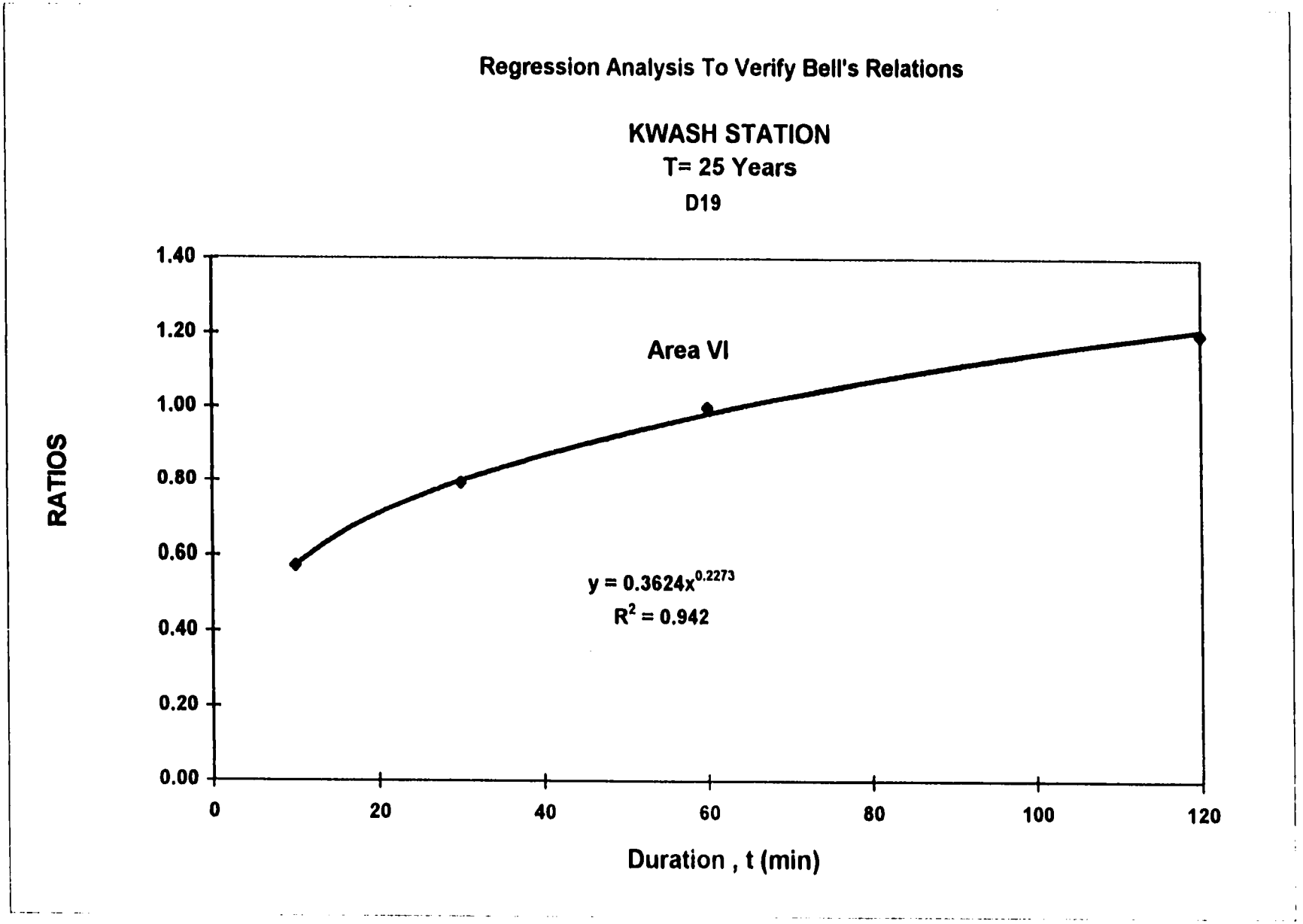
Regression Analysis To Verify Bell's Relations

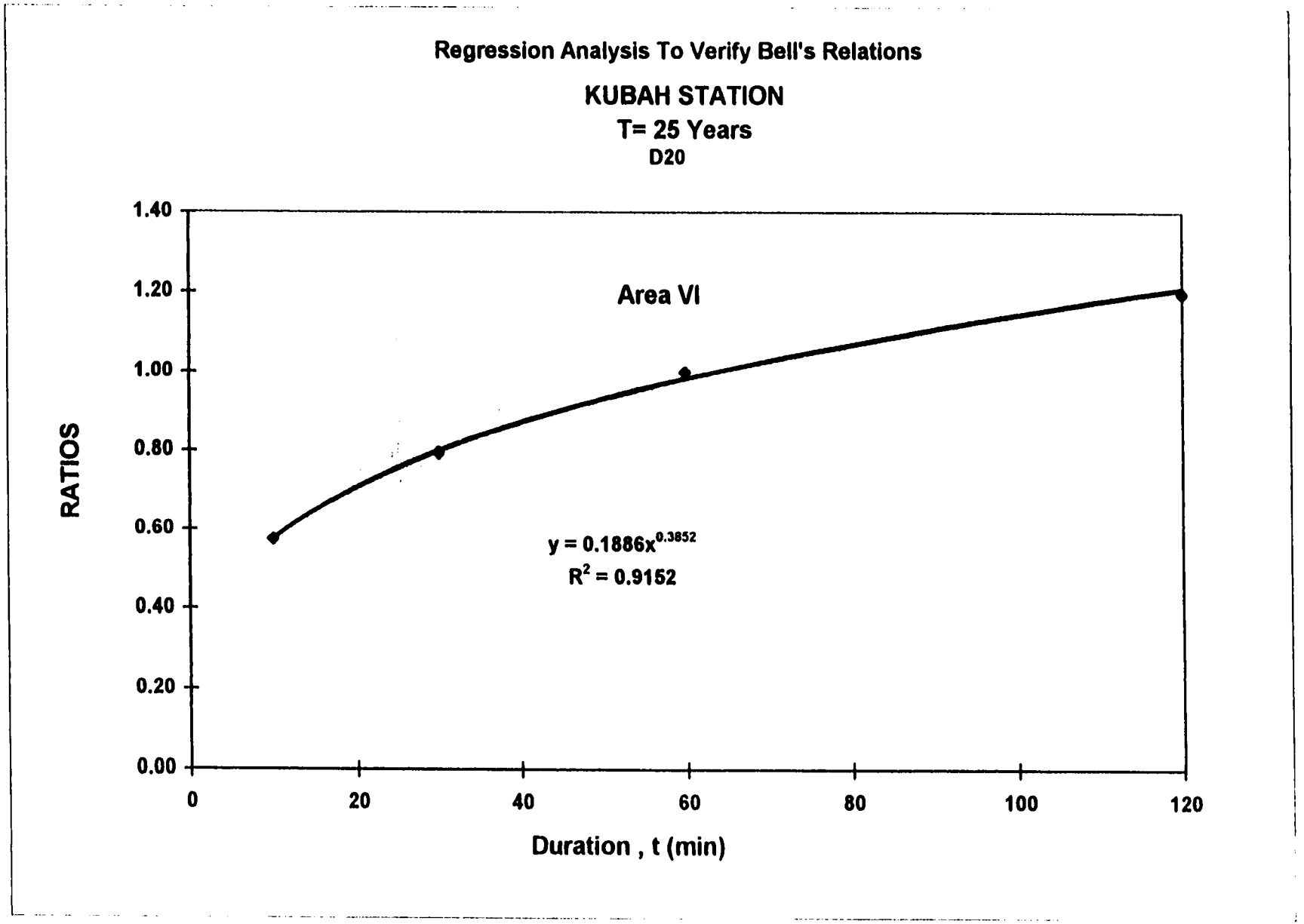
SUWAYDRAH STATION
T= 25 Years

D17




Regression Analysis To Verify Bell's Relations
AL MEDINAH FARM STATION
T= 25 Years
D18
Area VI
y = 0.2896x^0.2985
R^2 = 0.9985
RATIOS
Duration , t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Bell's Relations
KWASH STATION
T= 25 Years
D19
RATIOS
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Area VI
y = 0.3624x^0.2273
R^2 = 0.942
0
20
40
60
80
100
120
Duration , t (min)

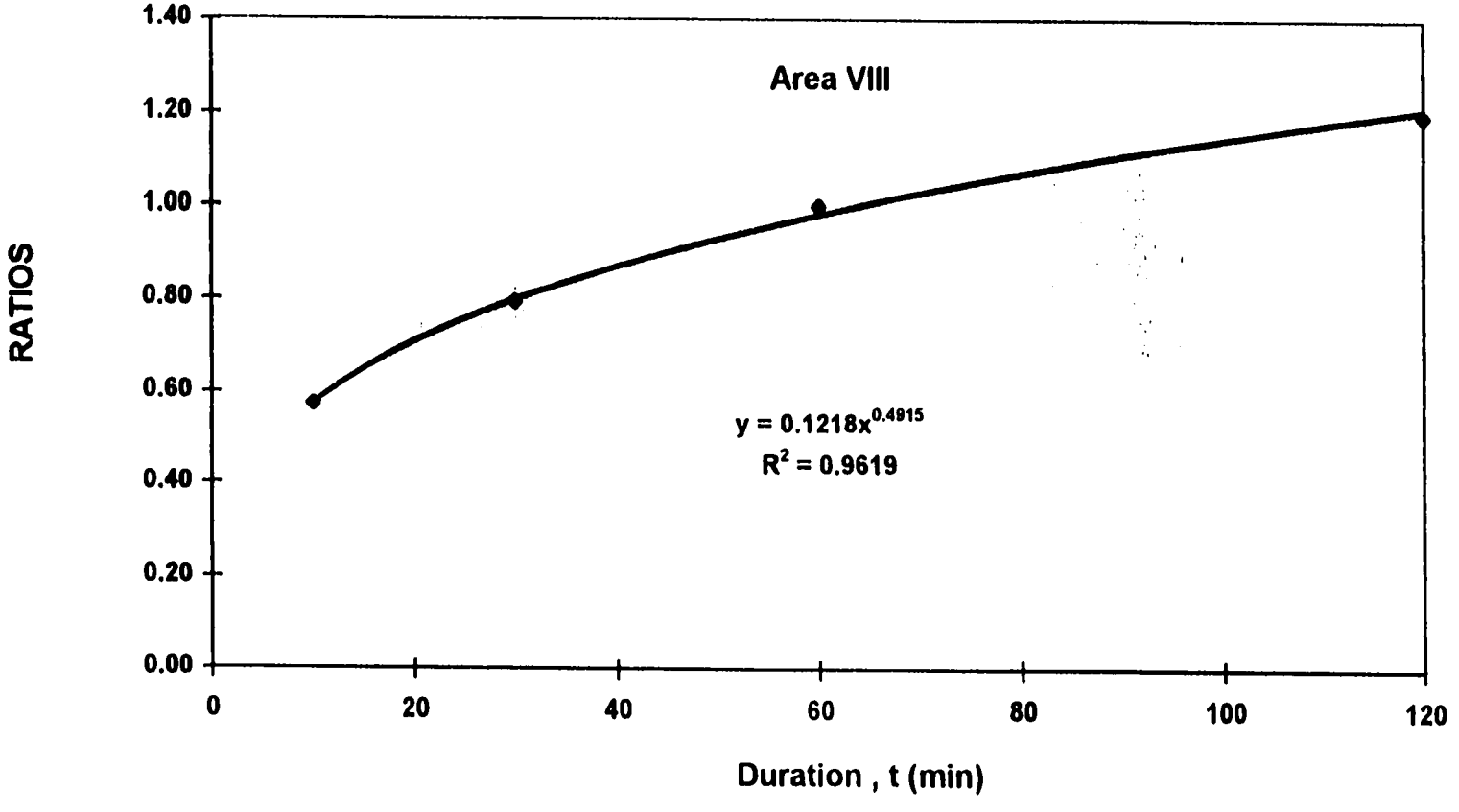

Regression Analysis To Verify Bell's Relations
KUBAH STATION
T= 25 Years
D20
Area VI
y = 0.1886x^0.3852
R^2 = 0.9152
RATIOS
Duration , t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120

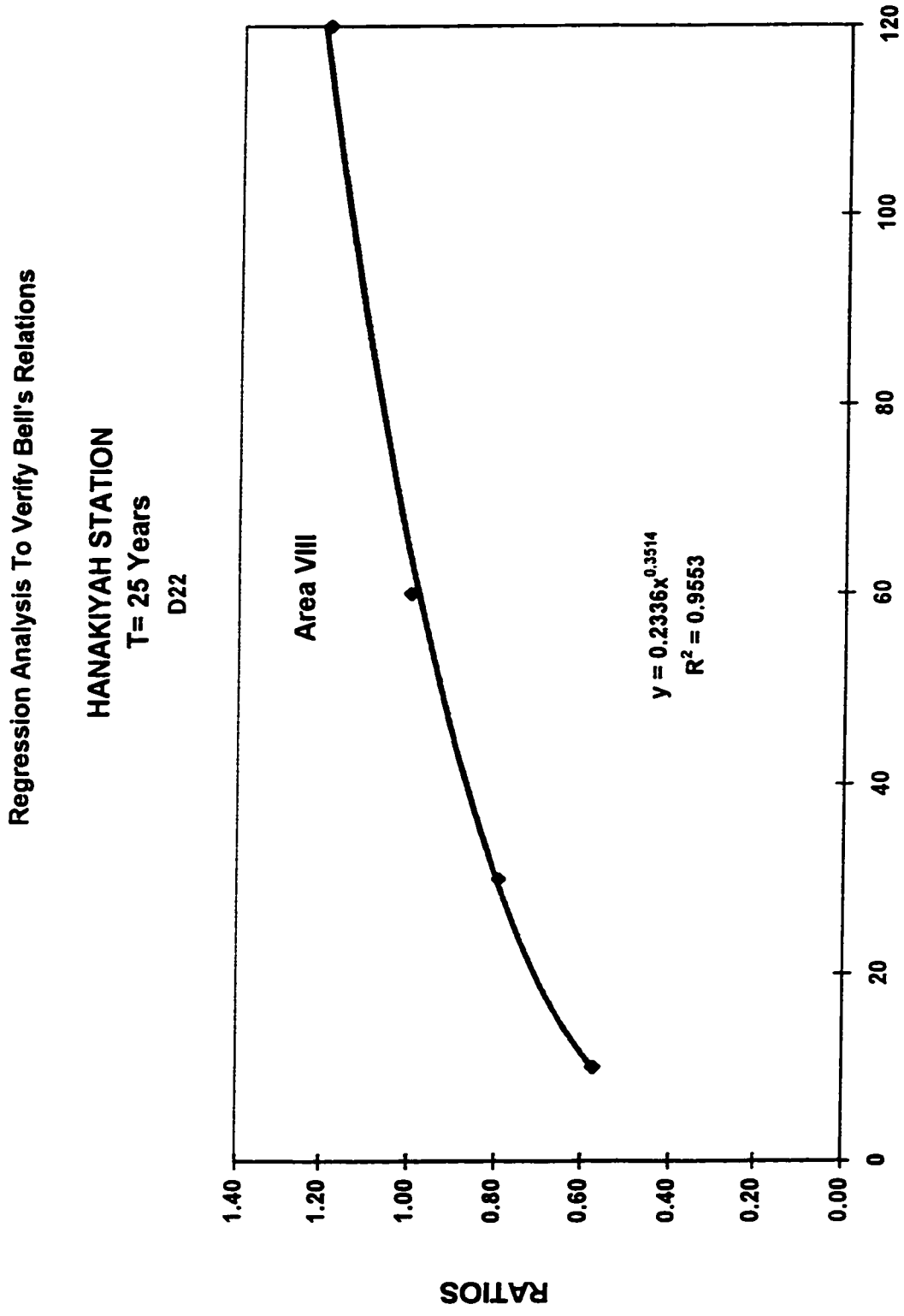
Regression Analysis To Verify Bell's Relations

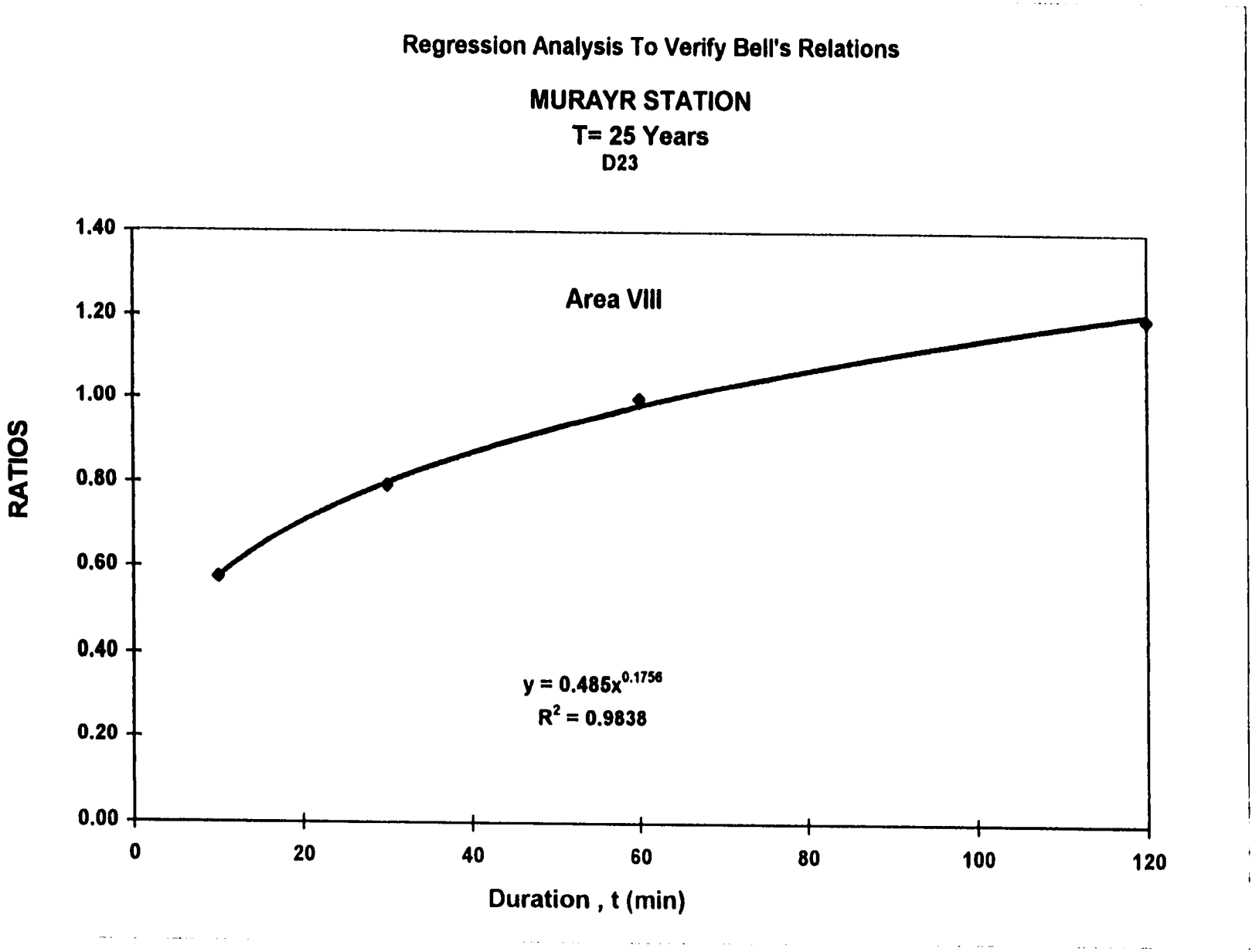
KIYAT STATION

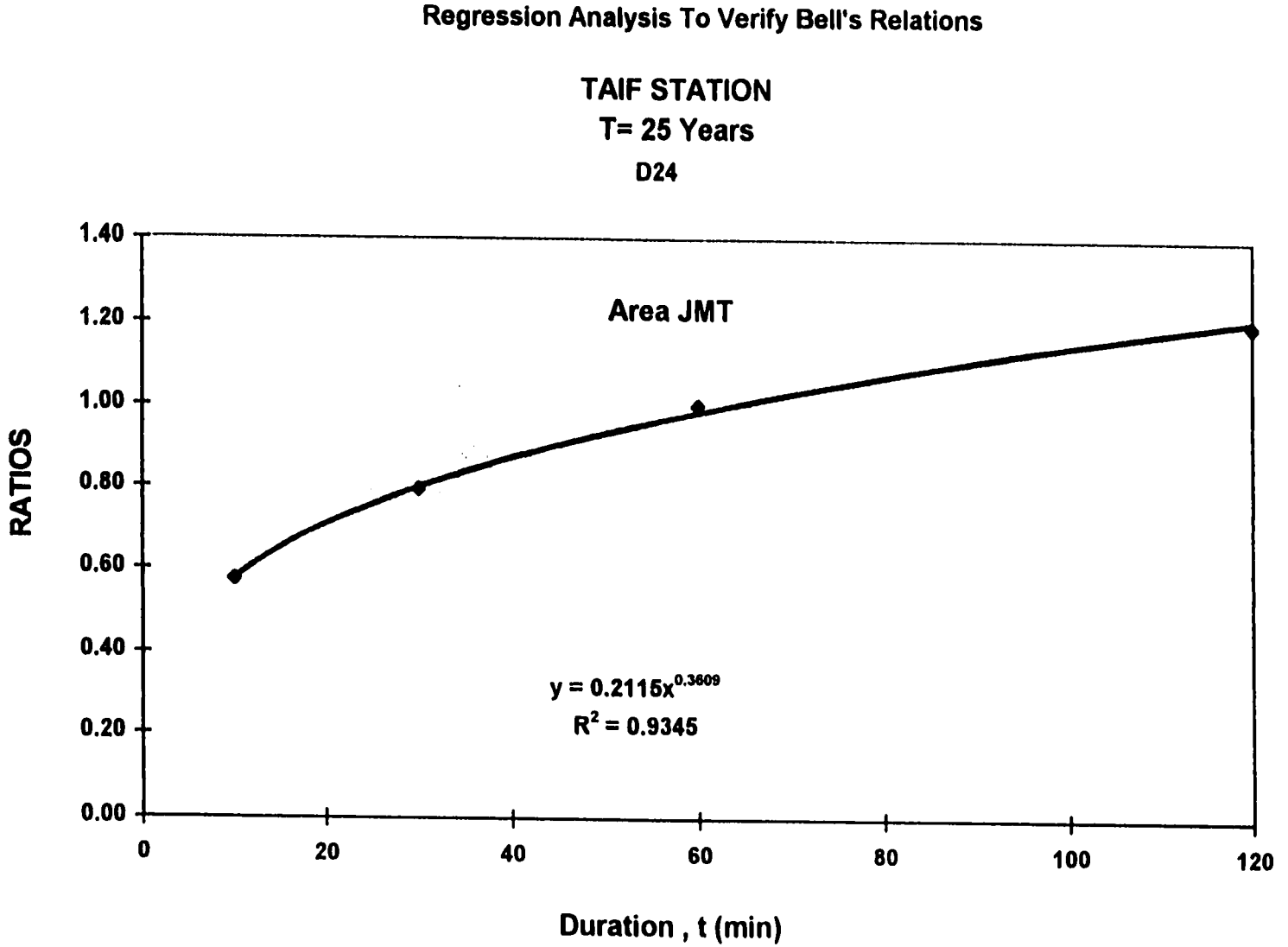
T= 25 Years

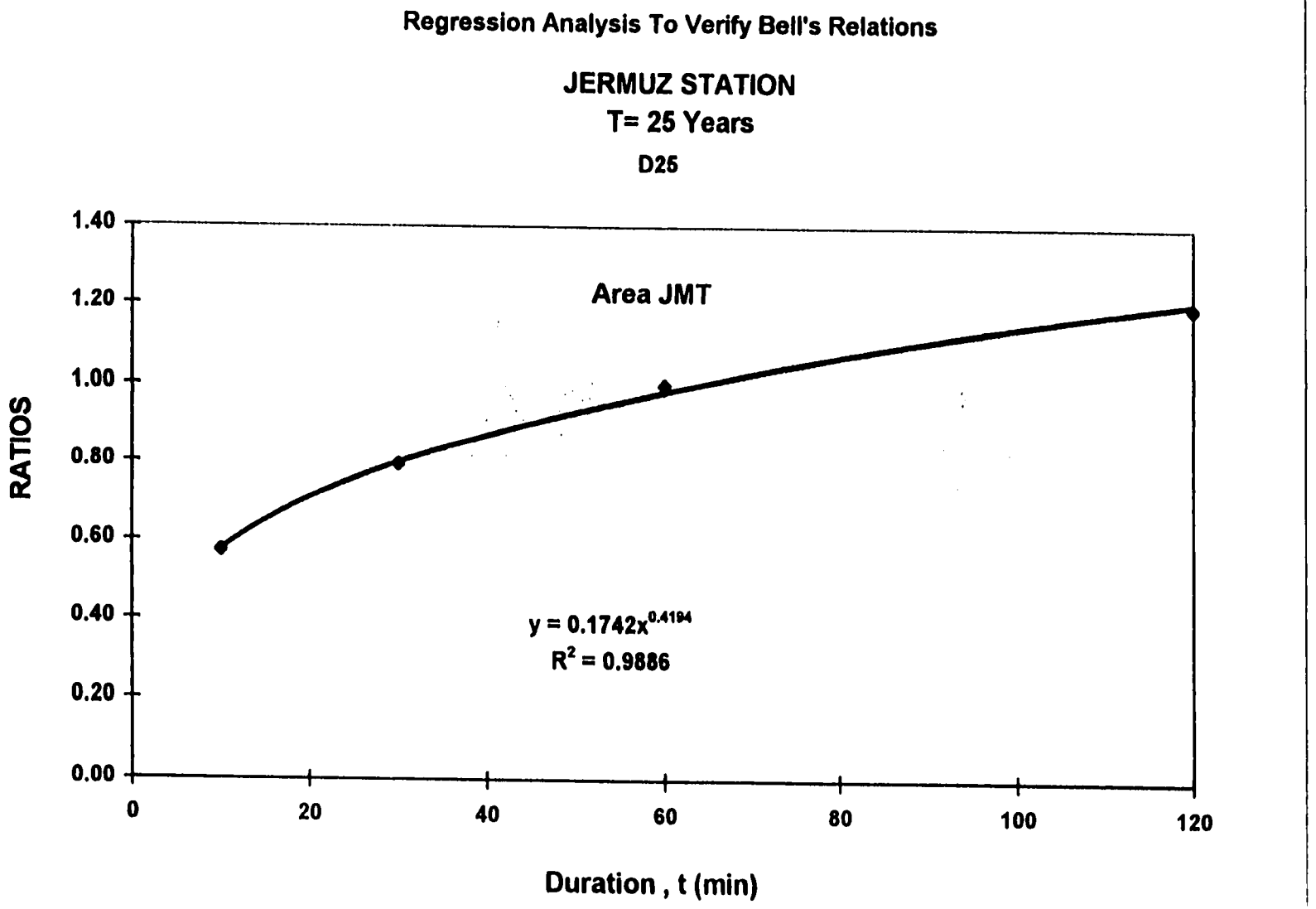
D21




Regression Analysis To Verify Bell's Relations
HANAKIYAH STATION
T= 25 Years
D22
Area VIII
y = 0.2336x^0.3514
R² = 0.9553
RATIOS
Duration , t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120

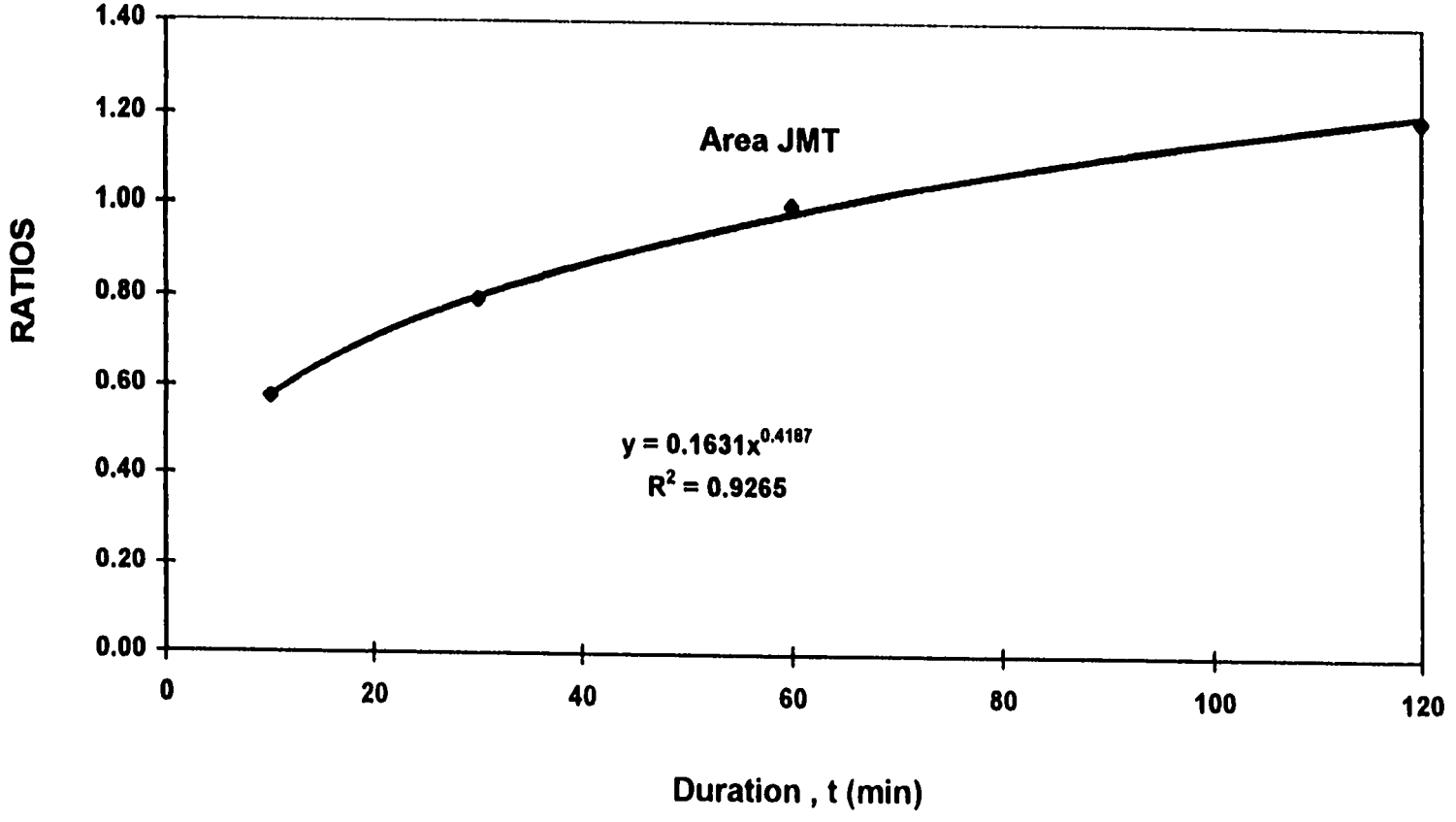

Regression Analysis To Verify Bell's Relations
MURAYR STATION
T= 25 Years
D23
Area VIII
y = 0.485x^0.1756
R^2 = 0.9838
RATIOS
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120
Duration , t (min)


Regression Analysis To Verify Bell's Relations
TAIF STATION
T= 25 Years
D24
Area JMT
y = 0.2115x^0.3609
R^2 = 0.9345
RATIOS
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120
Duration , t (min)

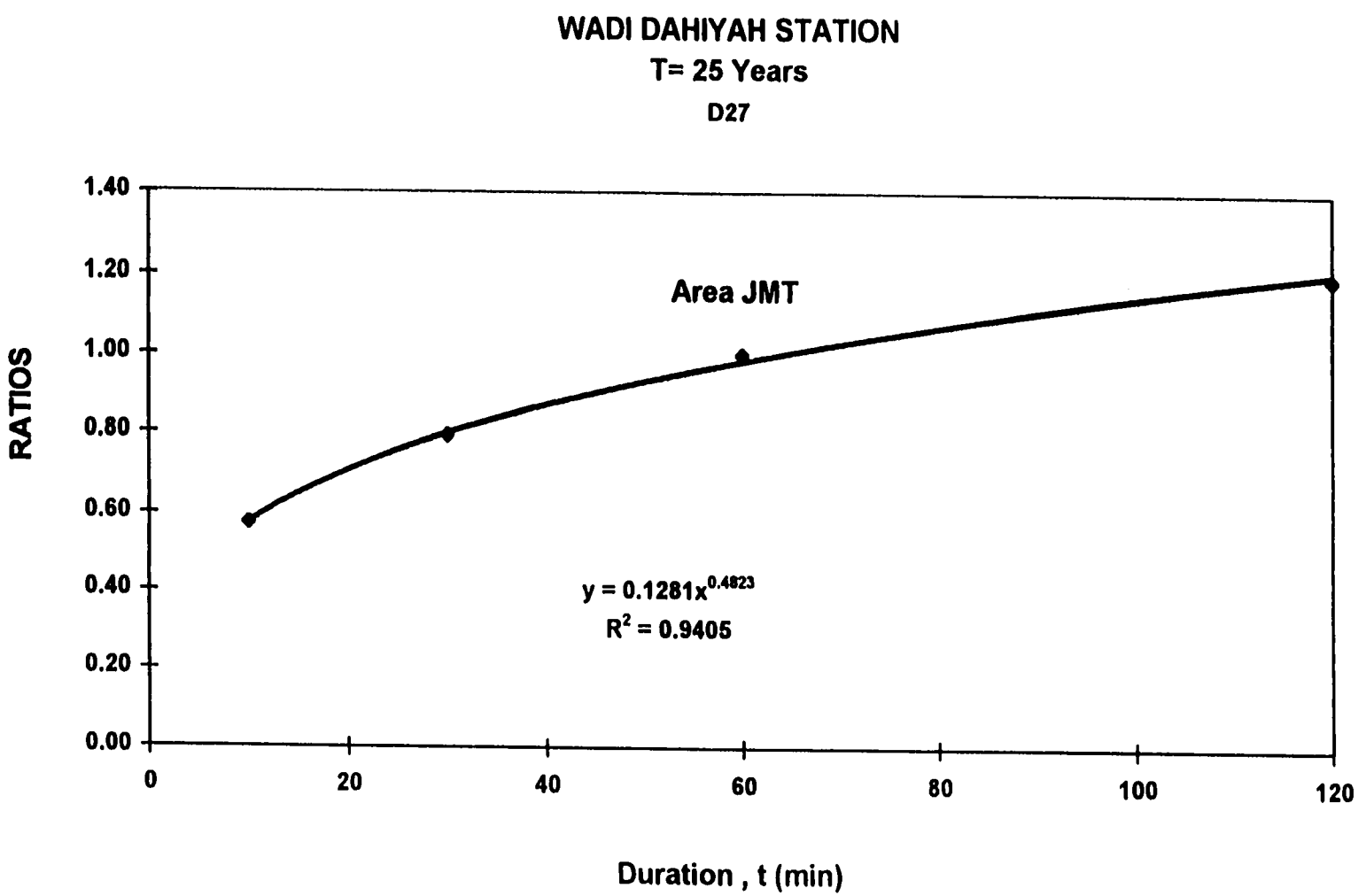

Regression Analysis To Verify Bell's Relations
JERMUZ STATION
T= 25 Years
D25
Area JMT
y = 0.1742x^0.4194
R^2 = 0.9886
RATIOS
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120
Duration , t (min)

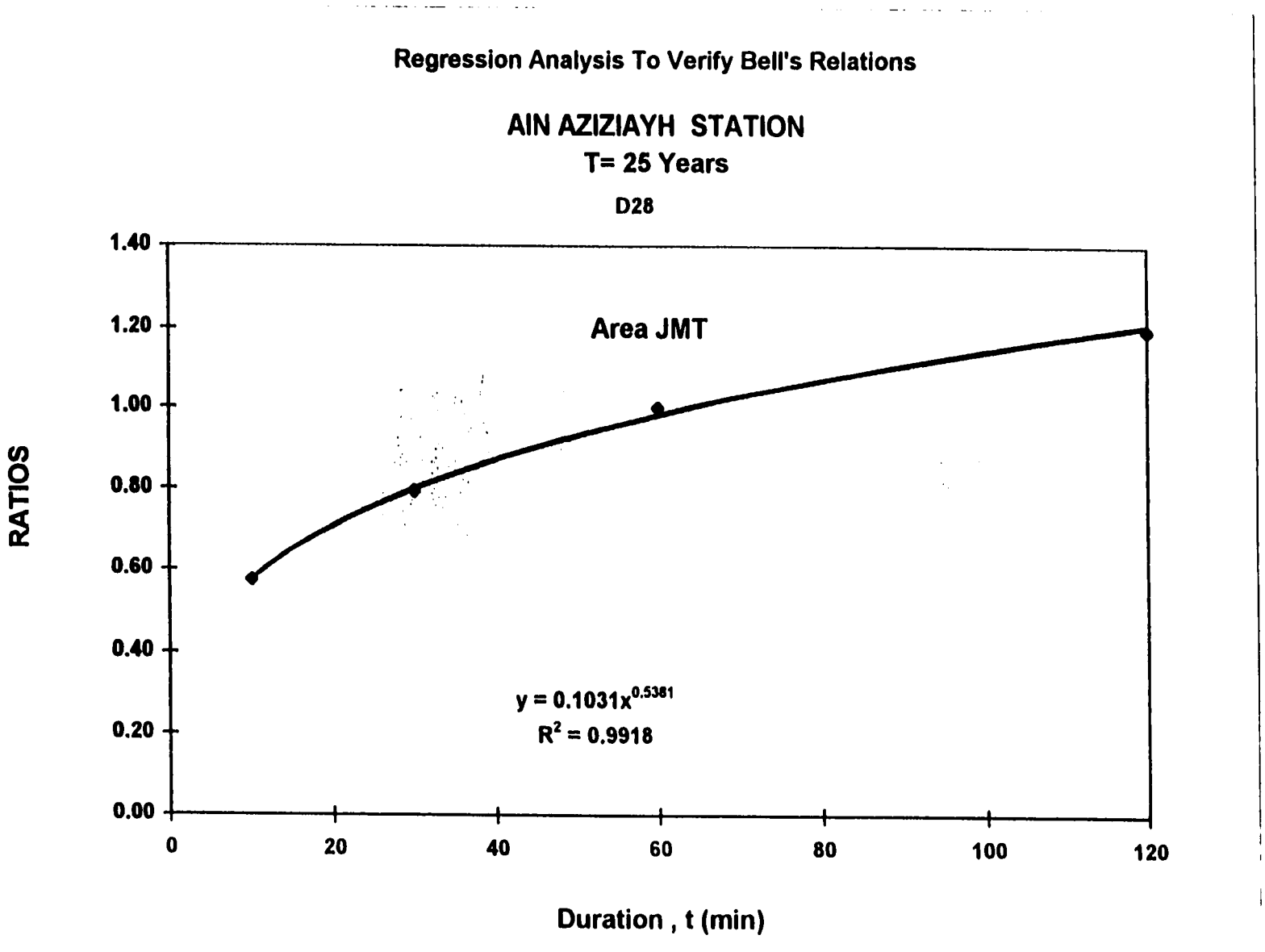
Regression Analysis To Verify Bell's Relations

HEMA SAYSID STATION
T= 25 Years
D26



Regression Analysis To Verify Bell's Relations



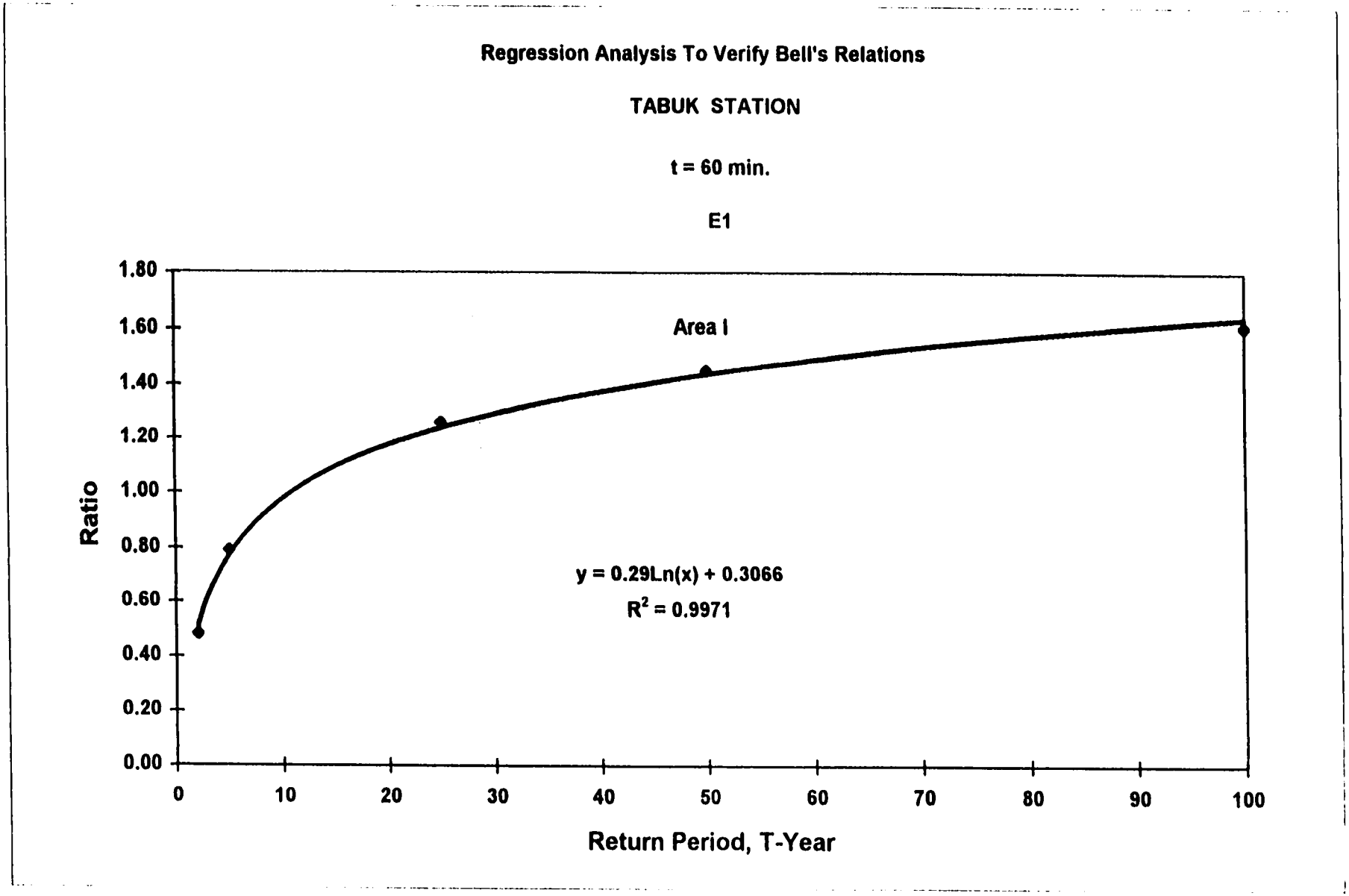

Regression Analysis To Verify Bell's Relations
AIN AZIZIAYH STATION
T= 25 Years
D28
Area JMT
y = 0.1031x^0.5381
R² = 0.9918
RATIOS
Duration , t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120

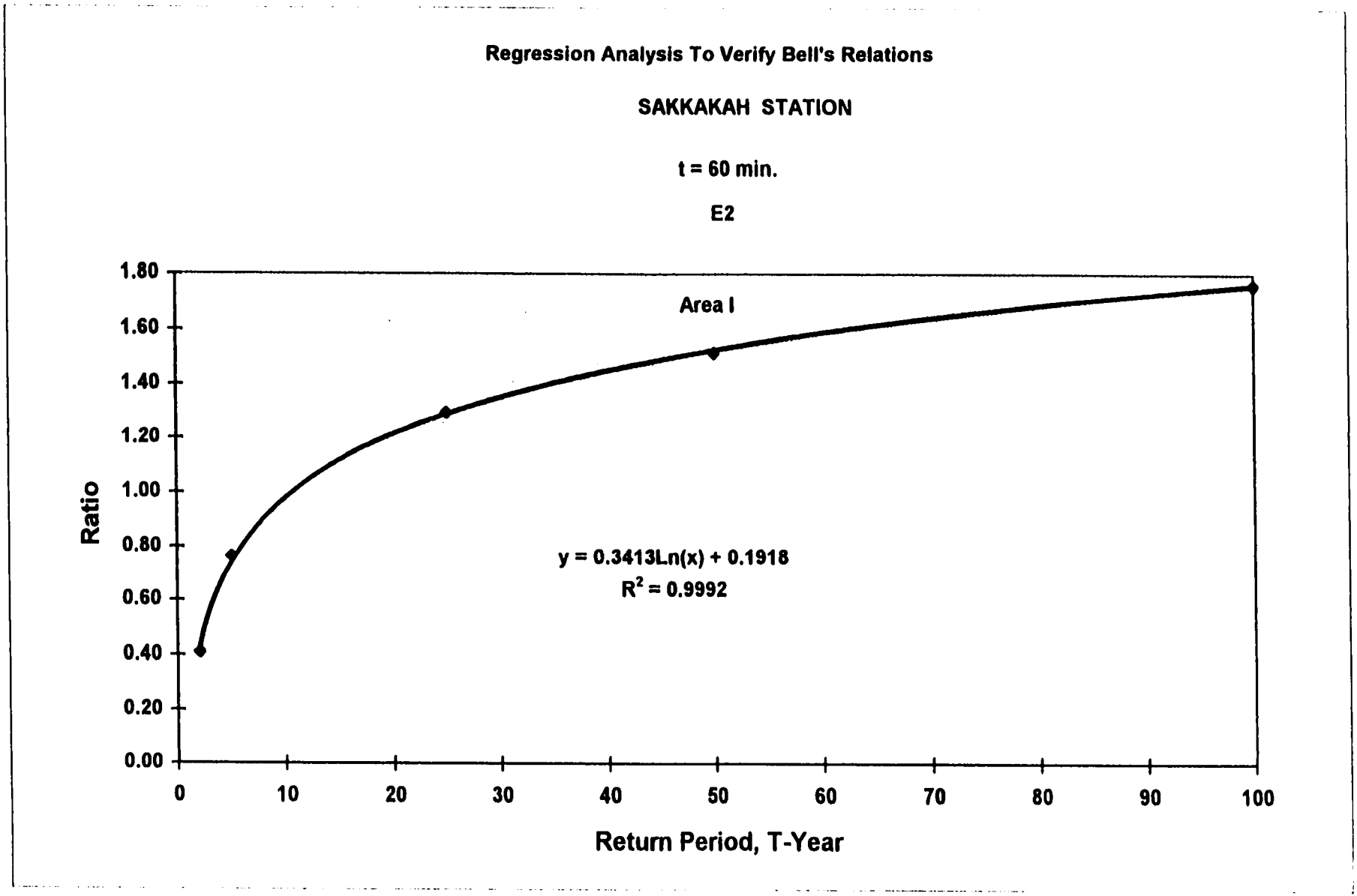
APPENDIX E

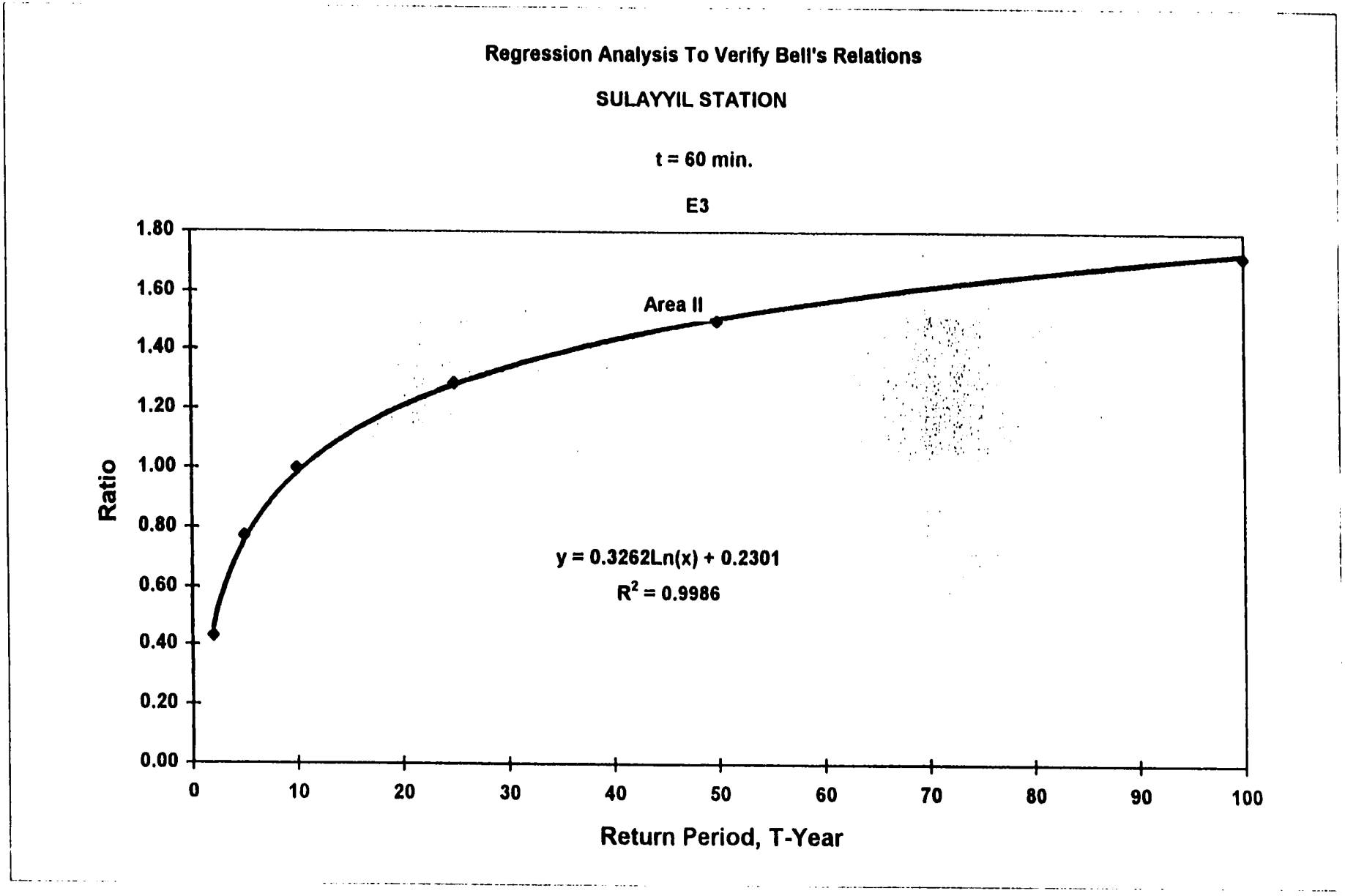
E_1 - E_{28}

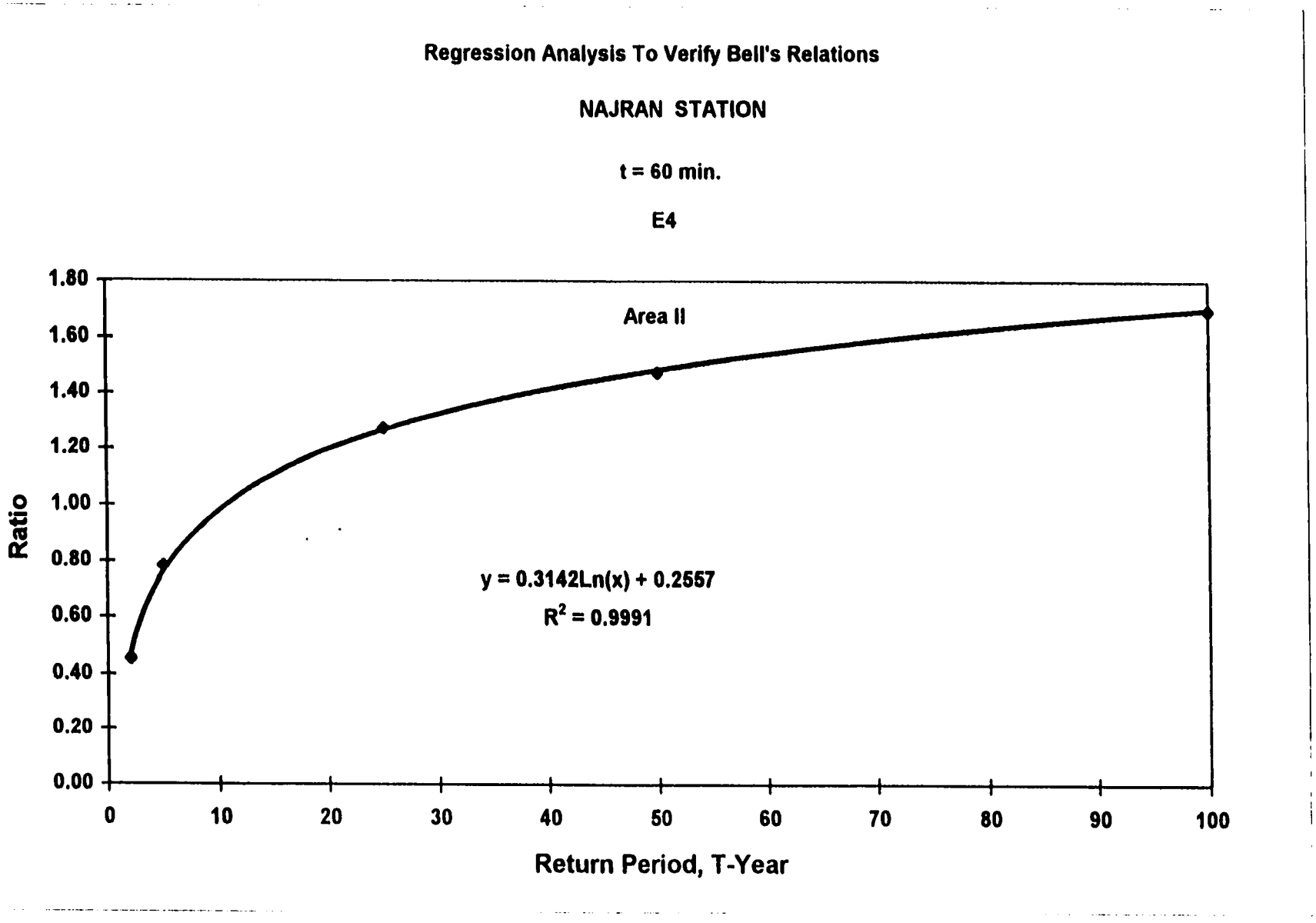
$$\frac{P_T^t}{P_{10}^t}$$

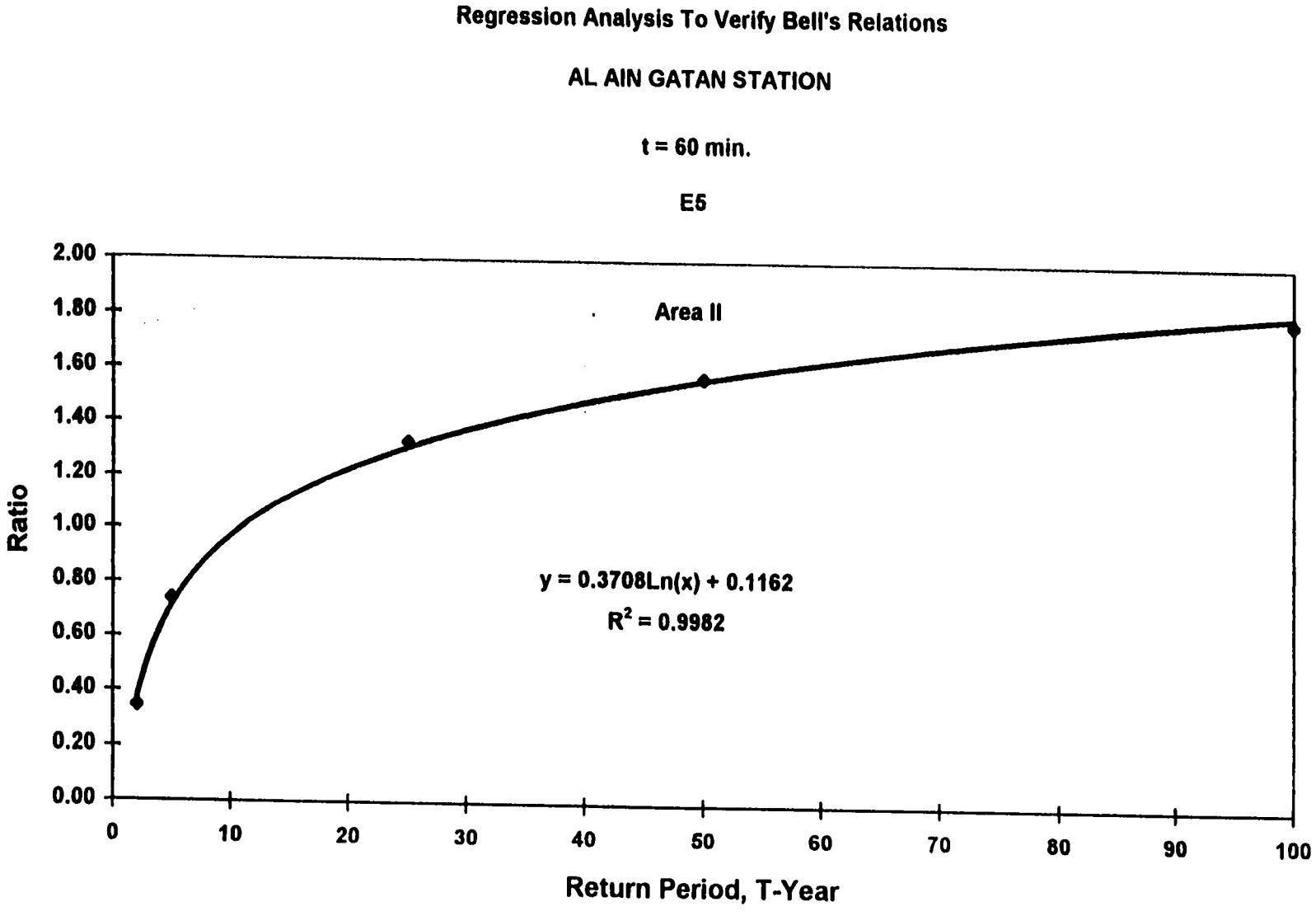
Model Curves

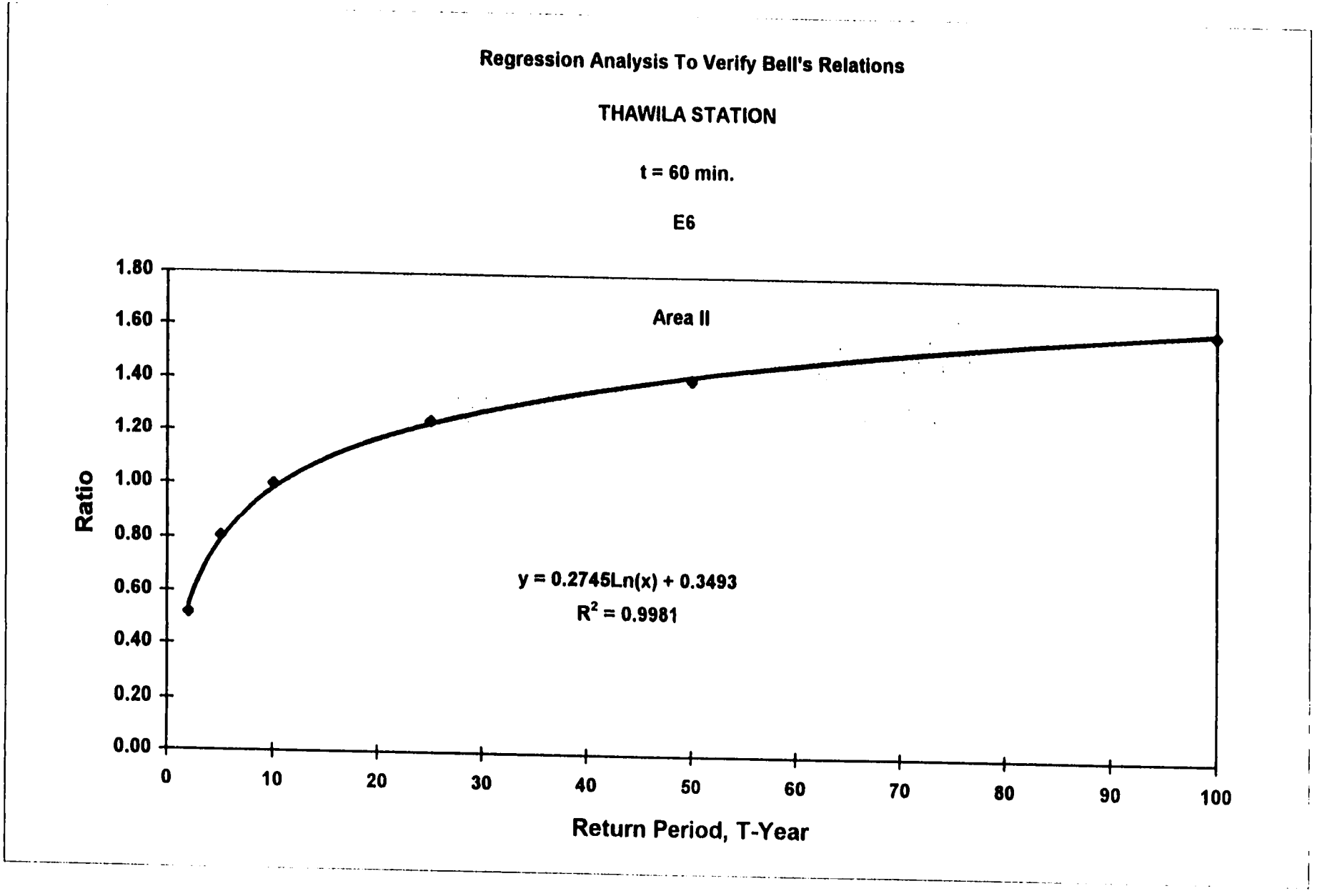

Regression Analysis To Verify Bell's Relations
TABUK STATION
t = 60 min.
E1
Area I
y = 0.29Ln(x) + 0.3066
R2 = 0.9971
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

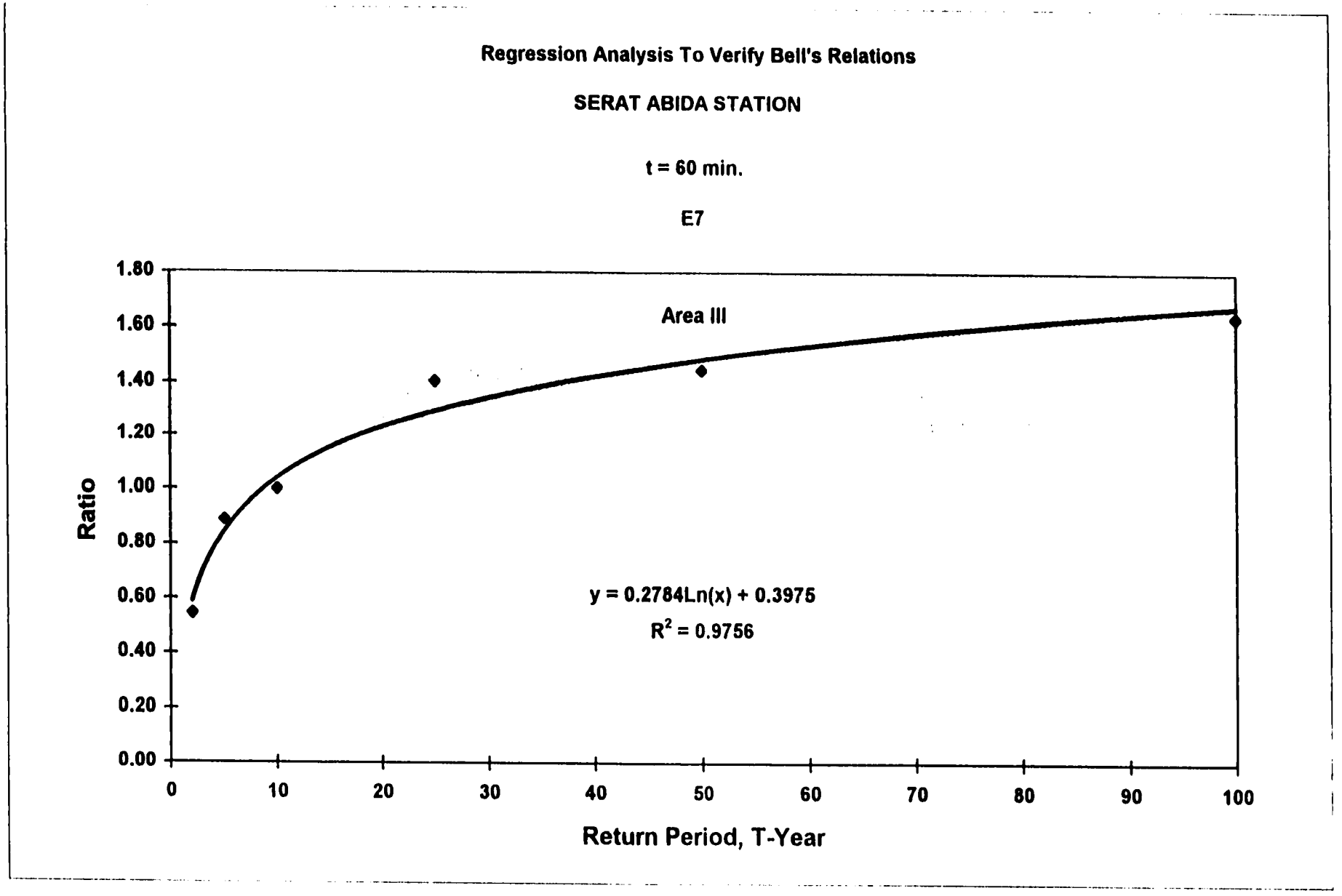

Regression Analysis To Verify Bell's Relations
SAKKAKAH STATION
t = 60 min.
E2
Area I
y = 0.3413Ln(x) + 0.1918
R2 = 0.9992
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

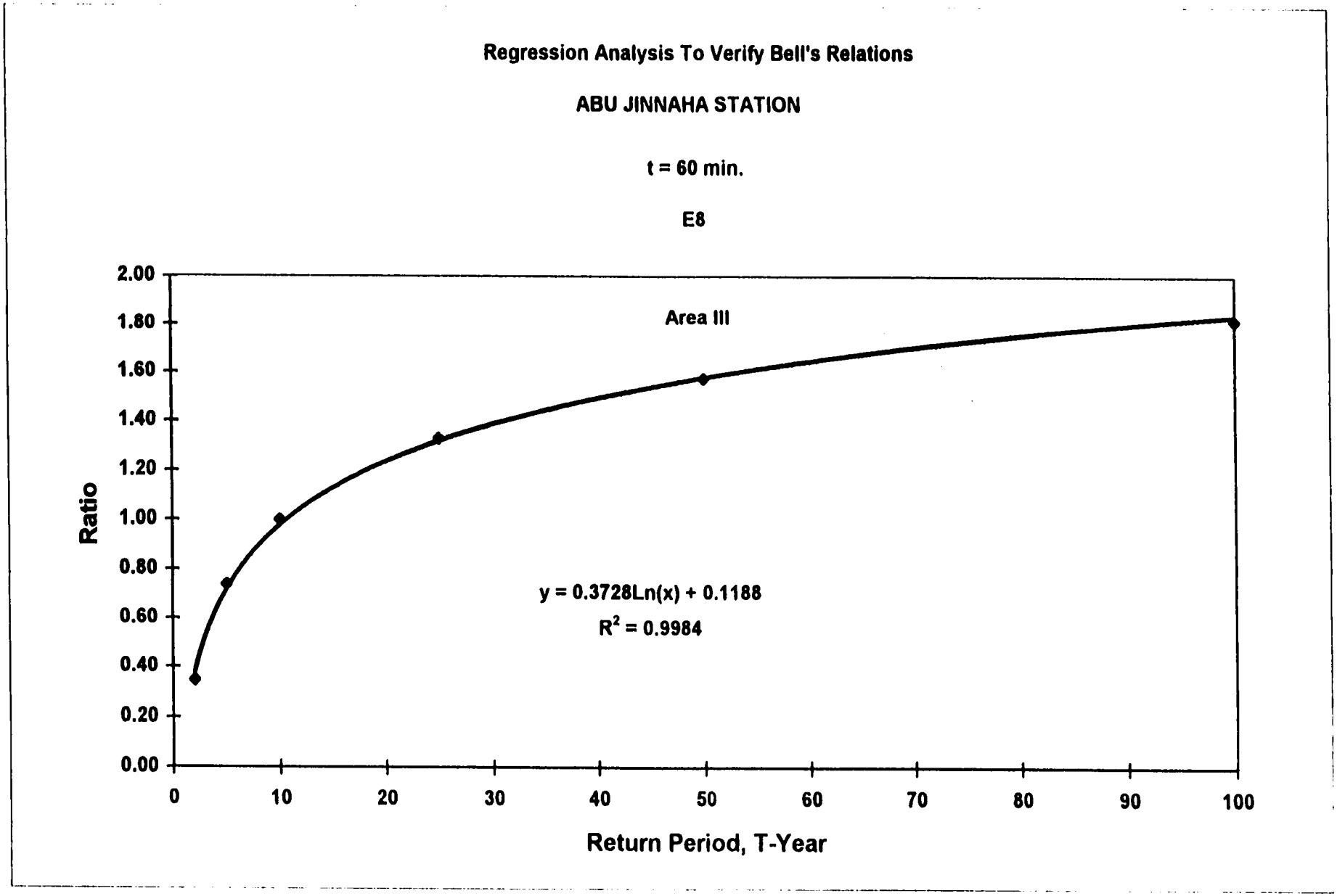

Regression Analysis To Verify Bell's Relations
SULAYYIL STATION
t = 60 min.
E3
Area II
y = 0.3262Ln(x) + 0.2301
R2 = 0.9986
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

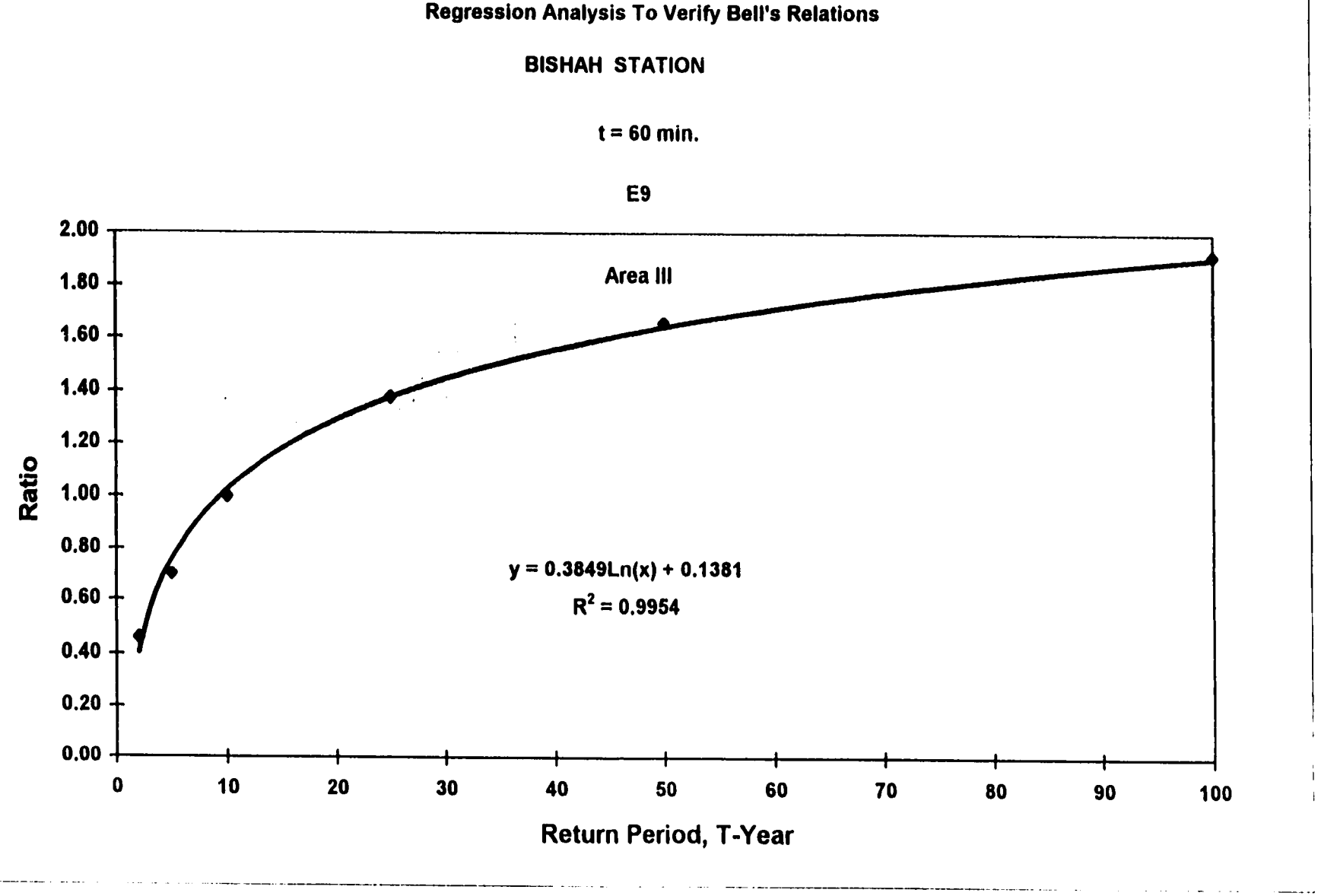

Regression Analysis To Verify Bell's Relations
NAJRAN STATION
t = 60 min.
E4
Area II
y = 0.3142Ln(x) + 0.2557
R2 = 0.9991
Ratio
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100
Return Period, T-Year

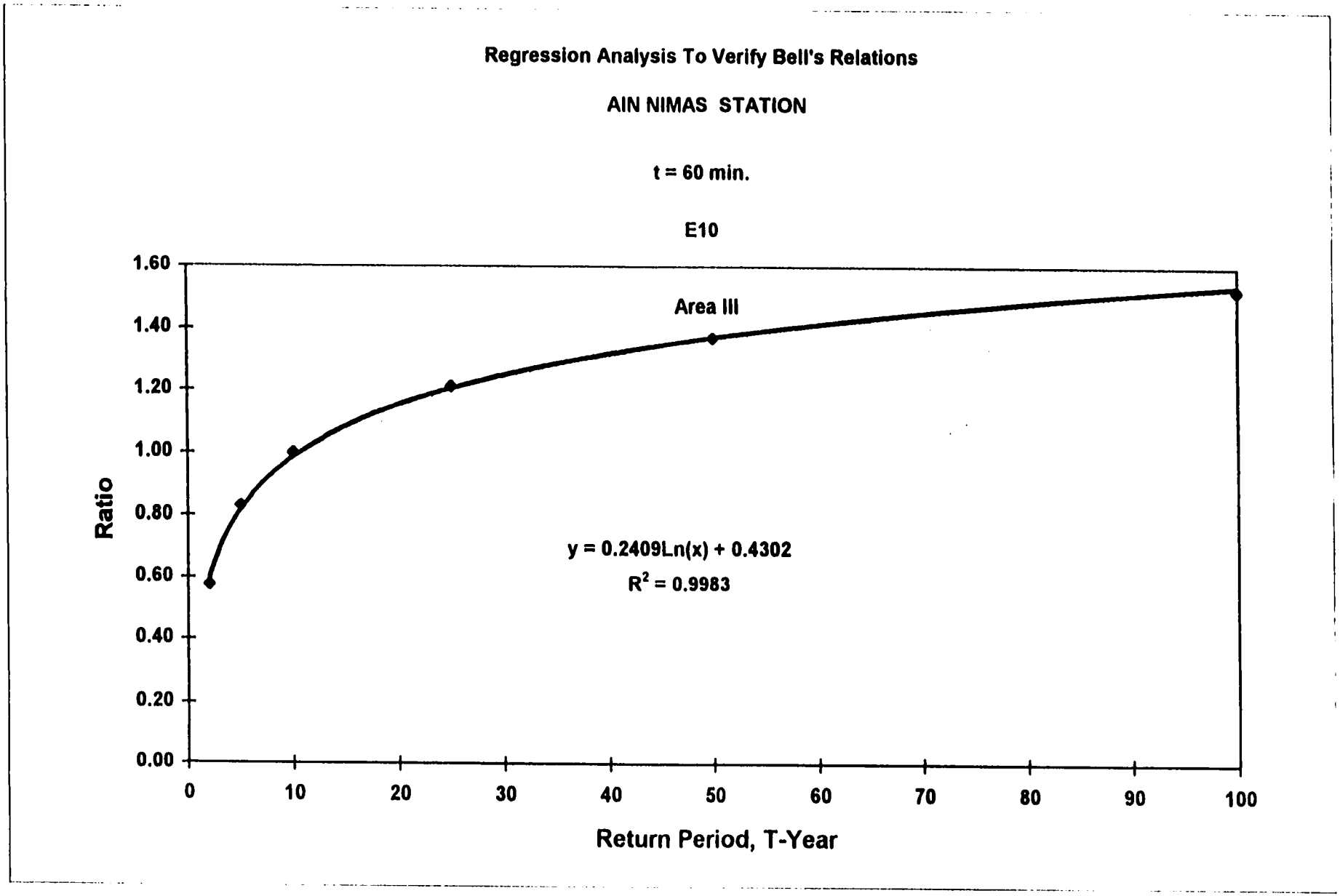

Regression Analysis To Verify Bell's Relations
AL AIN GATAN STATION
t = 60 min.
E5
Area II
y = 0.3708Ln(x) + 0.1162
R2 = 0.9982
Ratio
Return Period, T-Year
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

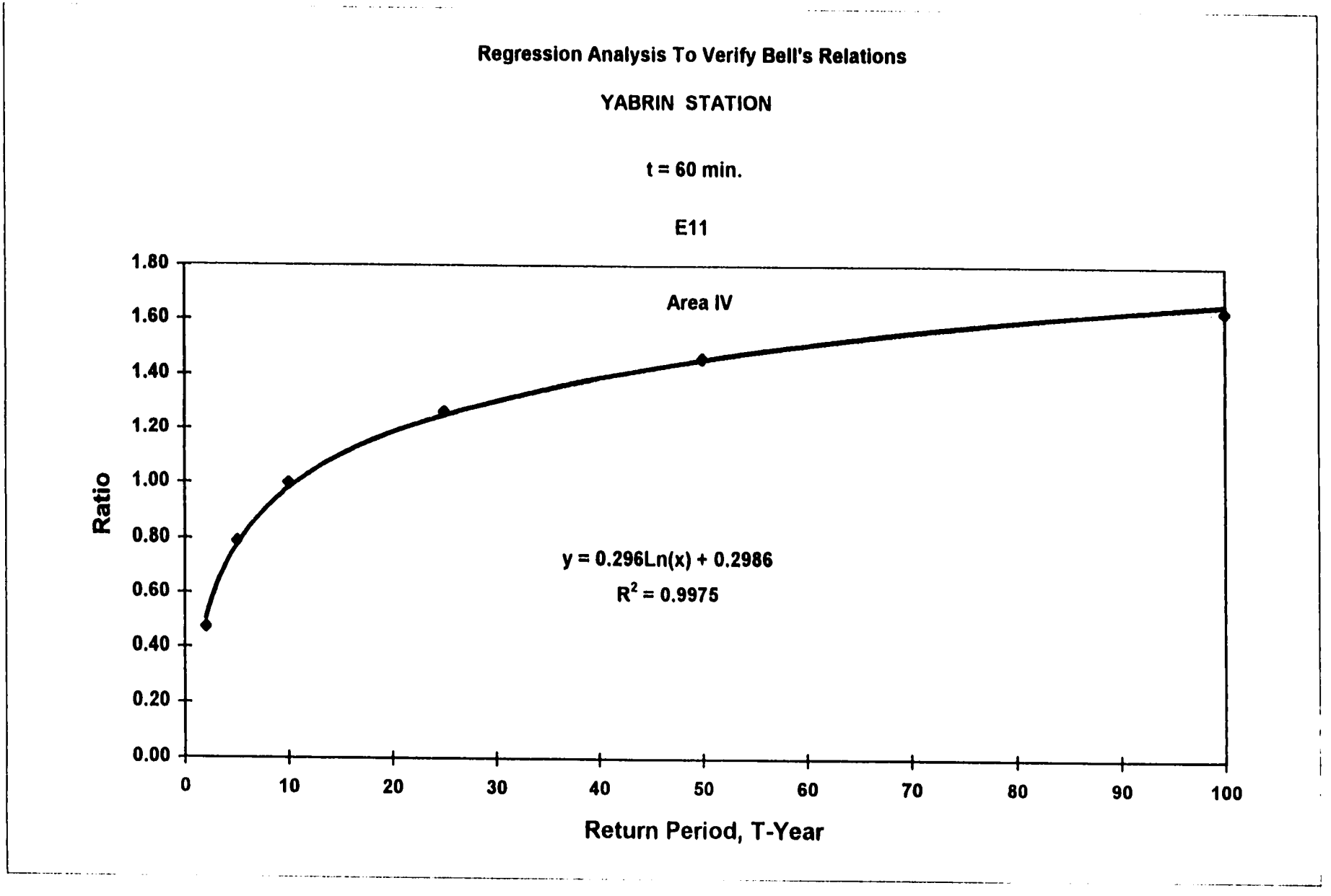

Regression Analysis To Verify Bell's Relations
THAWILA STATION
t = 60 min.
E6
Area II
y = 0.2745Ln(x) + 0.3493
R2 = 0.9981
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

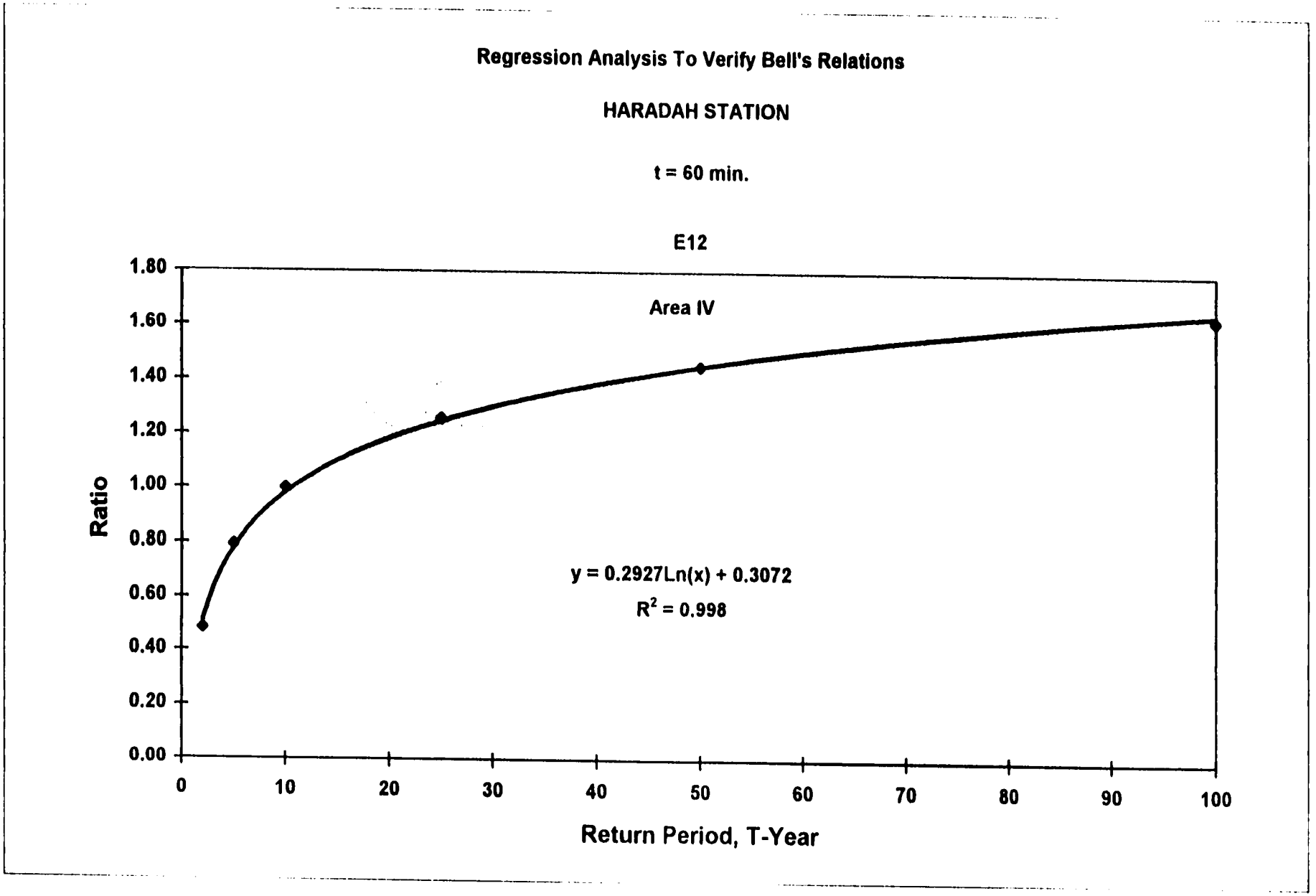

Regression Analysis To Verify Bell's Relations
SERAT ABIDA STATION
t = 60 min.
E7
Area III
y = 0.2784Ln(x) + 0.3975
R2 = 0.9756
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

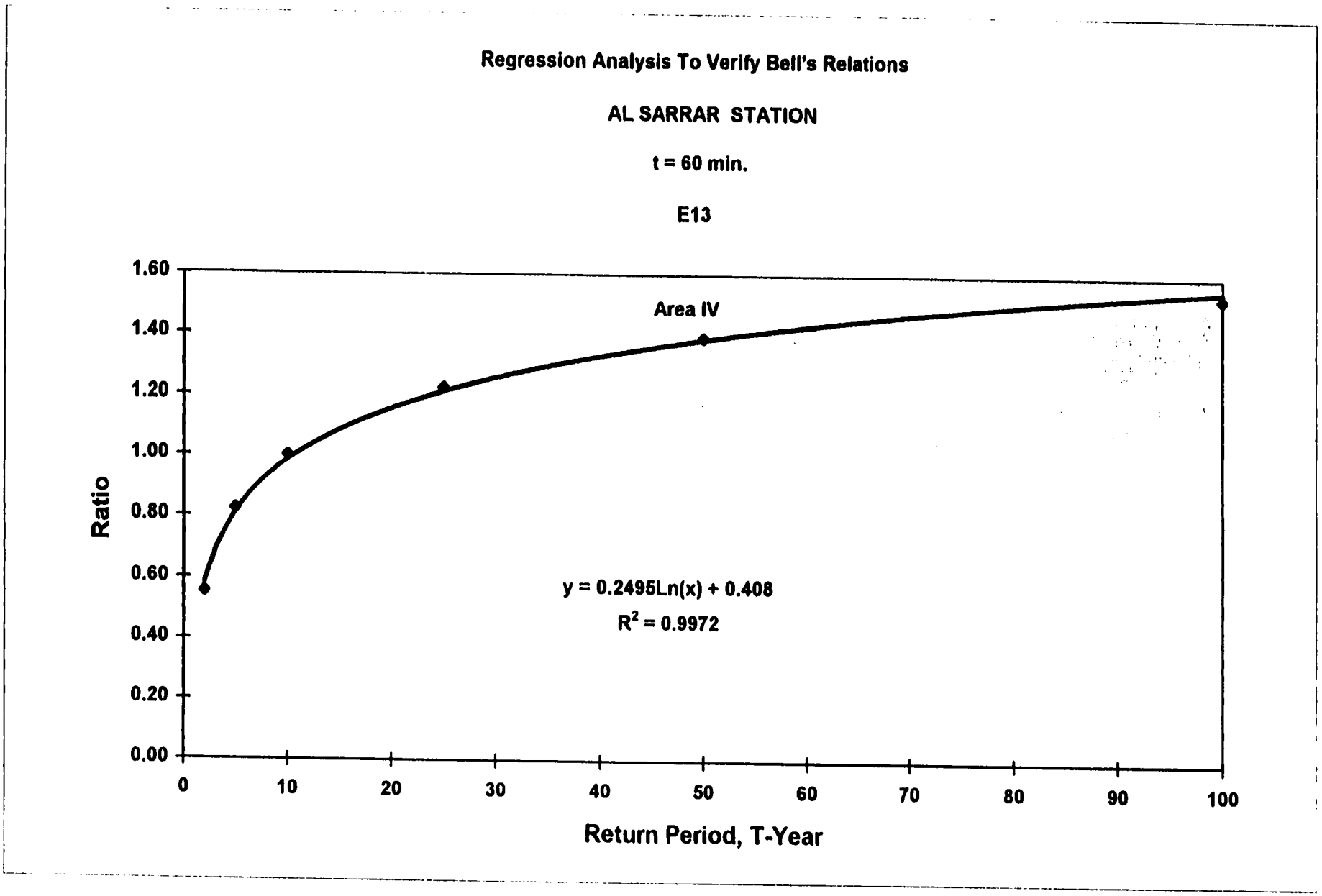

Regression Analysis To Verify Bell's Relations
ABU JINNAHA STATION
t = 60 min.
E8
Area III
y = 0.3728Ln(x) + 0.1188
R2 = 0.9984
Ratio
Return Period, T-Year
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

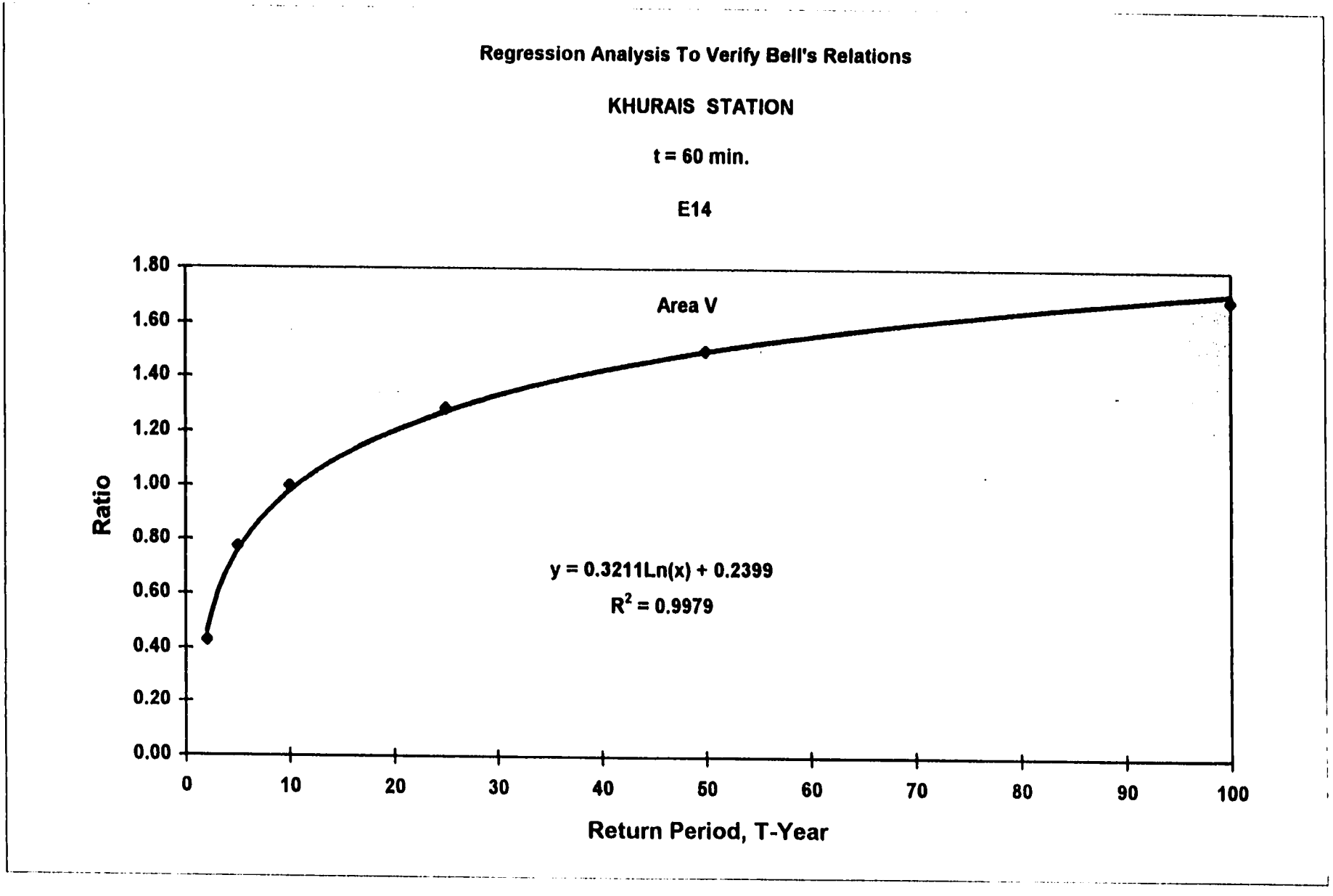

Regression Analysis To Verify Bell's Relations
BISHAH STATION
t = 60 min.
E9
Area III
y = 0.3849Ln(x) + 0.1381
R2 = 0.9954
Ratio
Return Period, T-Year
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

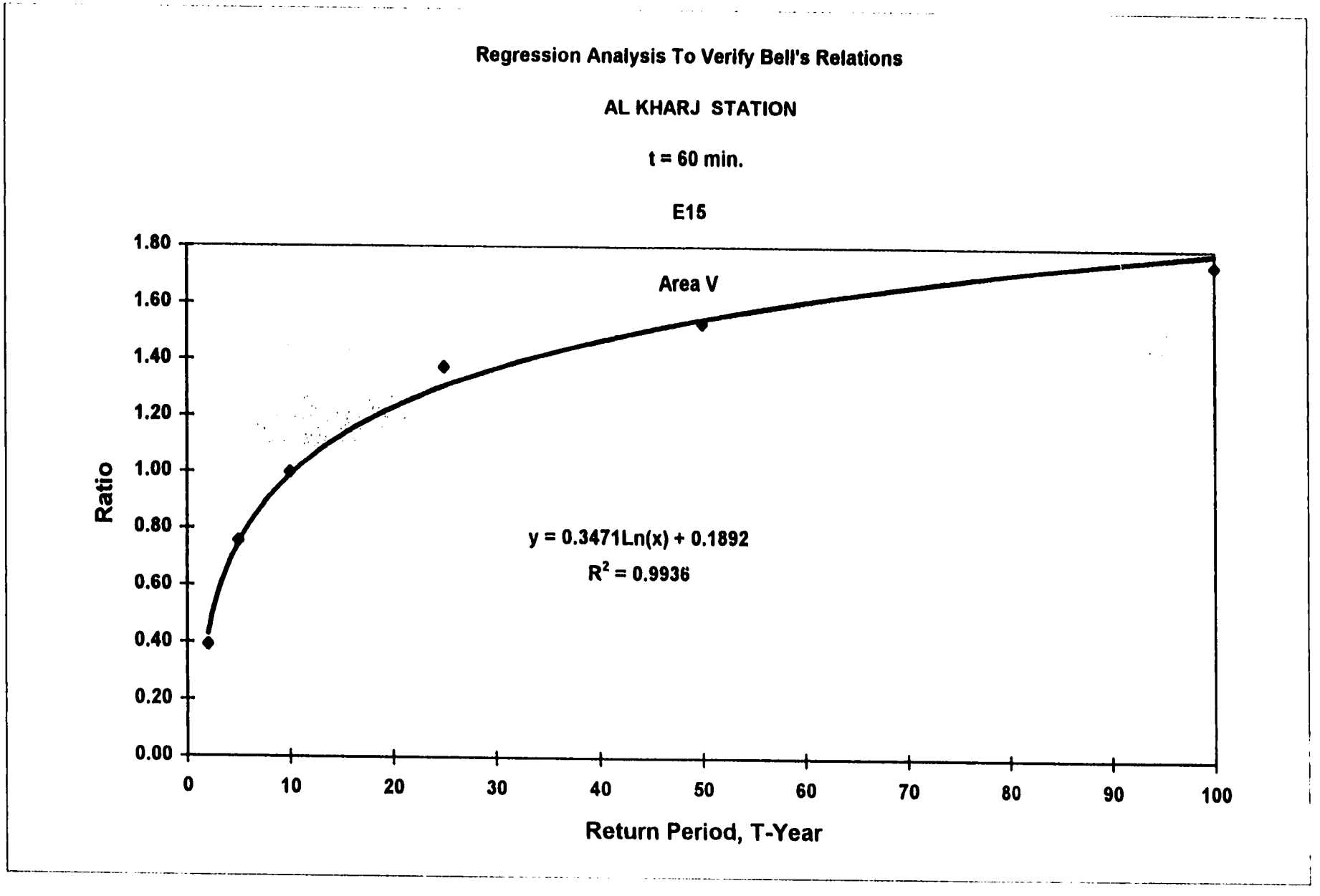

Regression Analysis To Verify Bell's Relations
AIN NIMAS STATION
t = 60 min.
E10
Area III
y = 0.2409Ln(x) + 0.4302
R² = 0.9983
Ratio
Return Period, T-Year
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

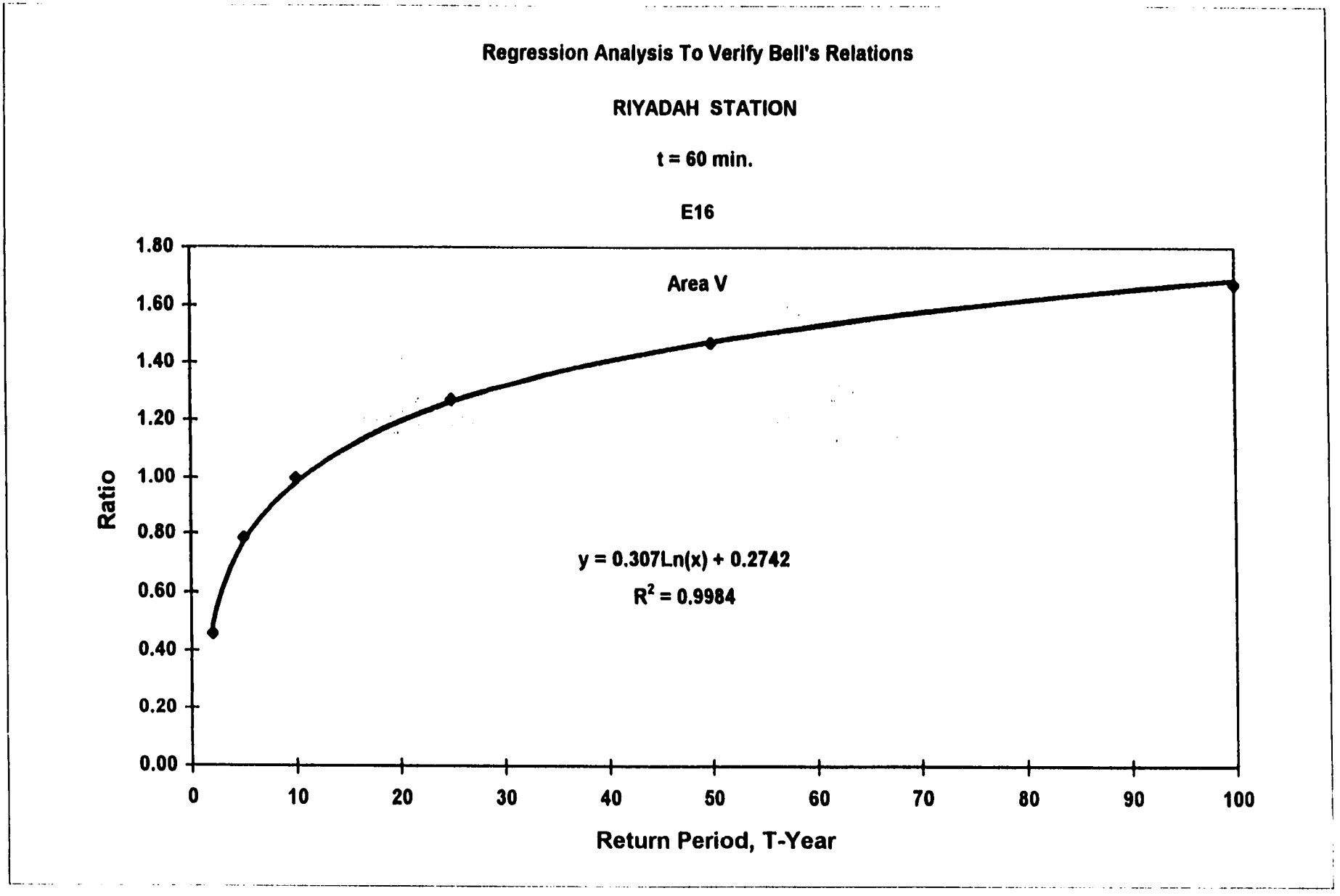

Regression Analysis To Verify Bell's Relations
YABRIN STATION
t = 60 min.
E11
Area IV
y = 0.296Ln(x) + 0.2986
R2 = 0.9975
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

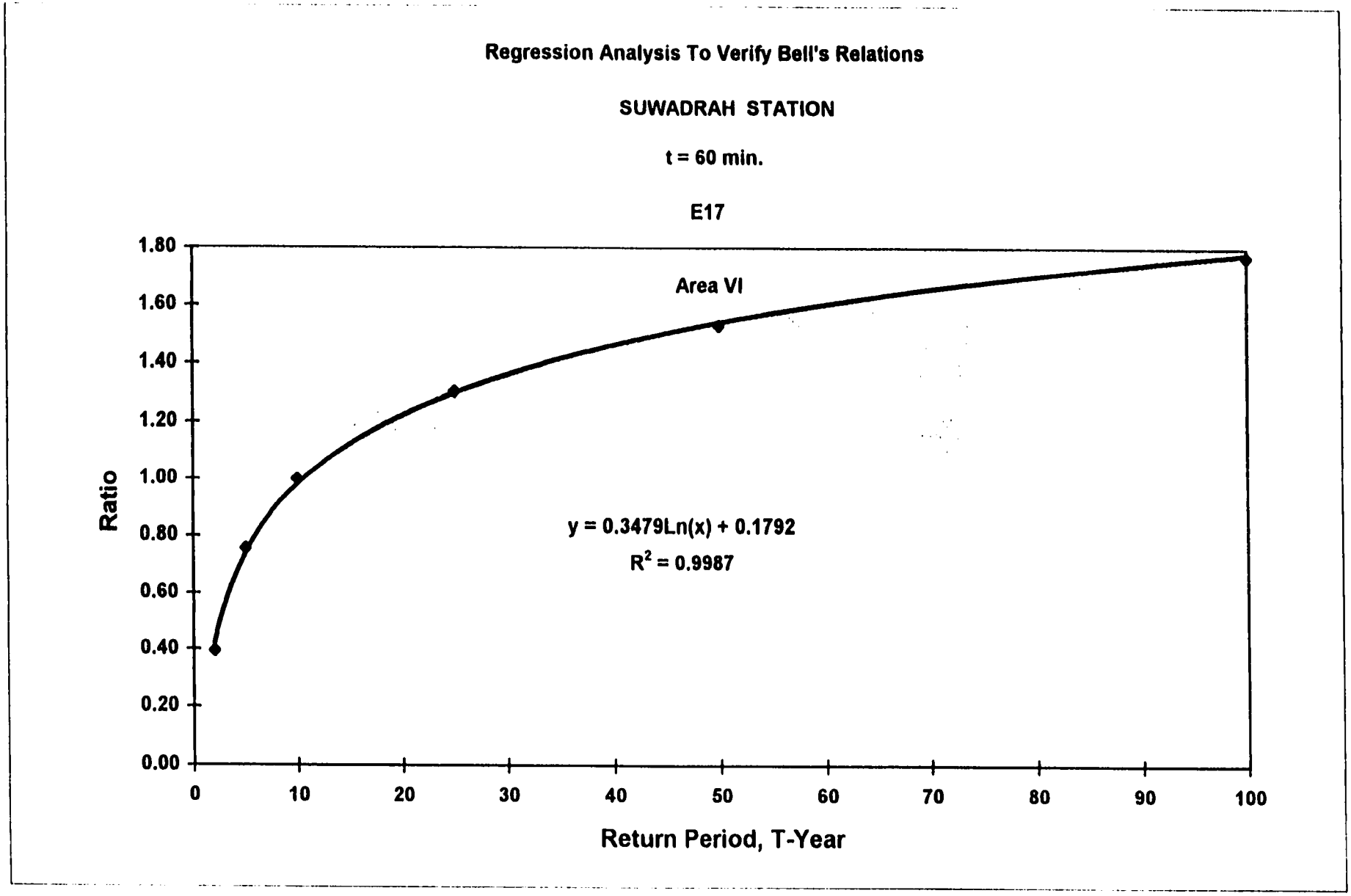

Regression Analysis To Verify Bell's Relations
HARADAH STATION
t = 60 min.
E12
Area IV
y = 0.2927Ln(x) + 0.3072
R2 = 0.998
Ratio
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100
Return Period, T-Year

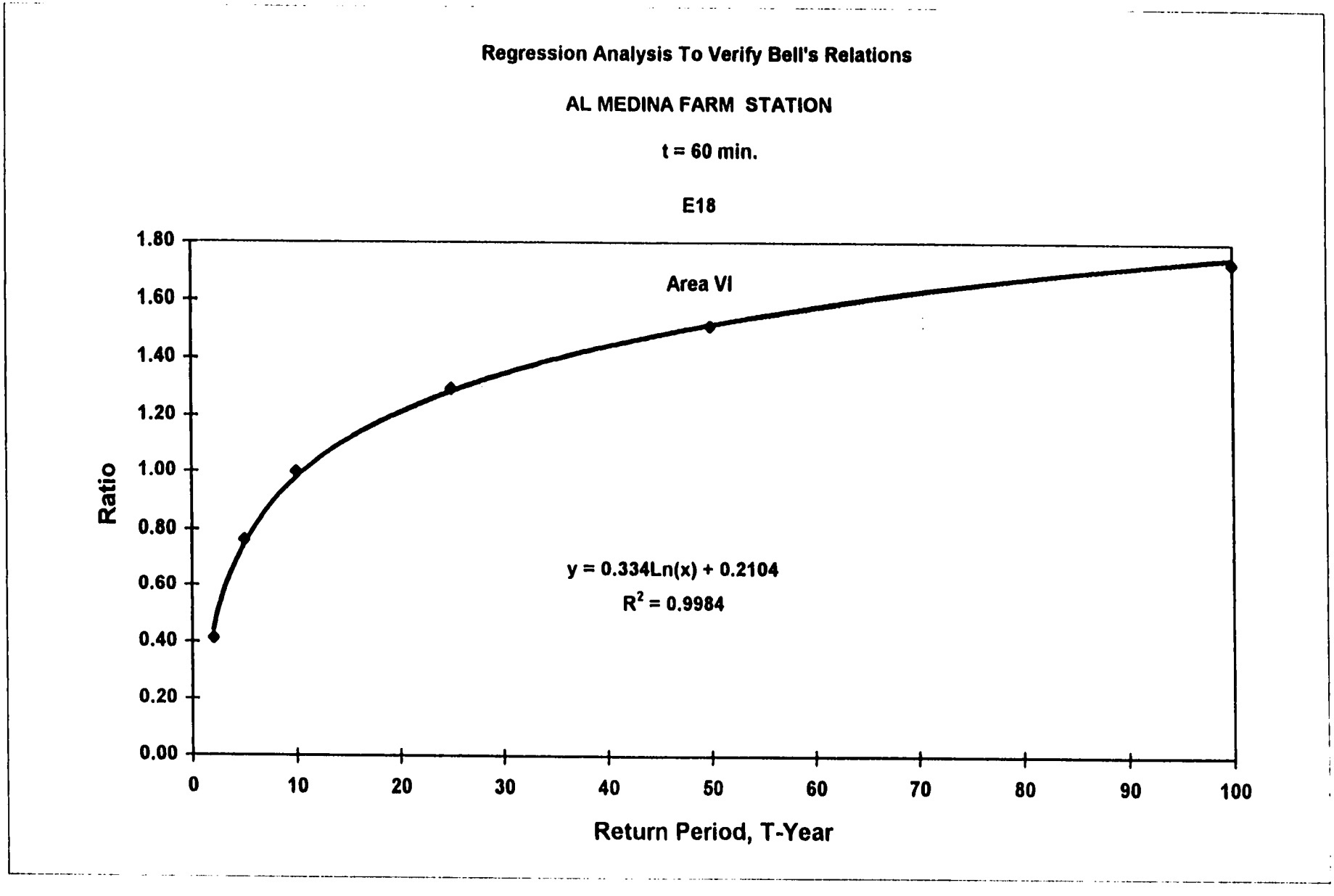

Regression Analysis To Verify Bell's Relations
AL SARRAR STATION
t = 60 min.
E13
Area IV
y = 0.2495Ln(x) + 0.408
R2 = 0.9972
Ratio
Return Period, T-Year
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

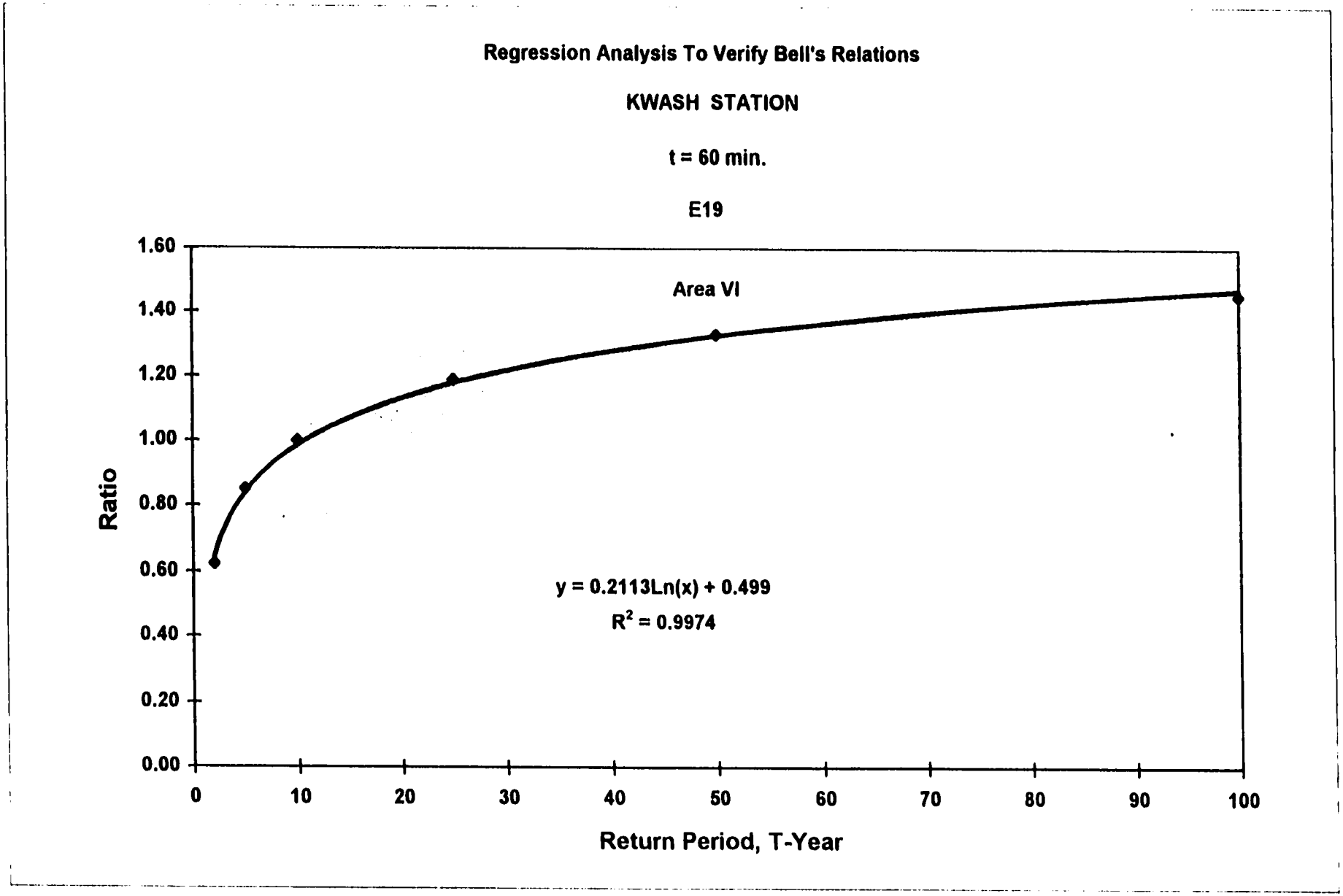

Regression Analysis To Verify Bell's Relations
KHURAIS STATION
t = 60 min.
E14
Area V
y = 0.3211Ln(x) + 0.2399
R2 = 0.9979
Ratio
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100
Return Period, T-Year

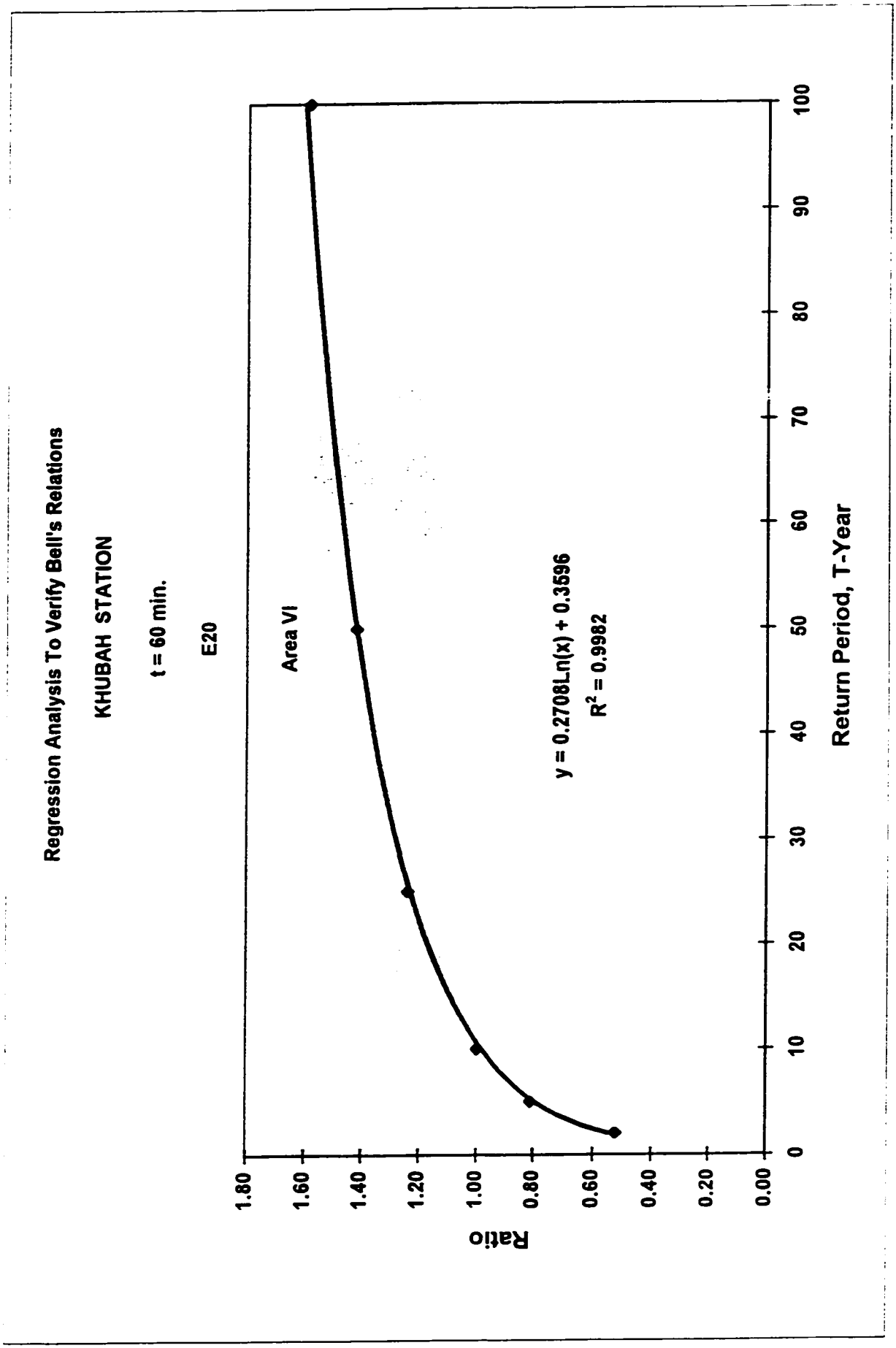

Regression Analysis To Verify Bell's Relations
AL KHARJ STATION
t = 60 min.
E15
Area V
y = 0.3471Ln(x) + 0.1892
R2 = 0.9936
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

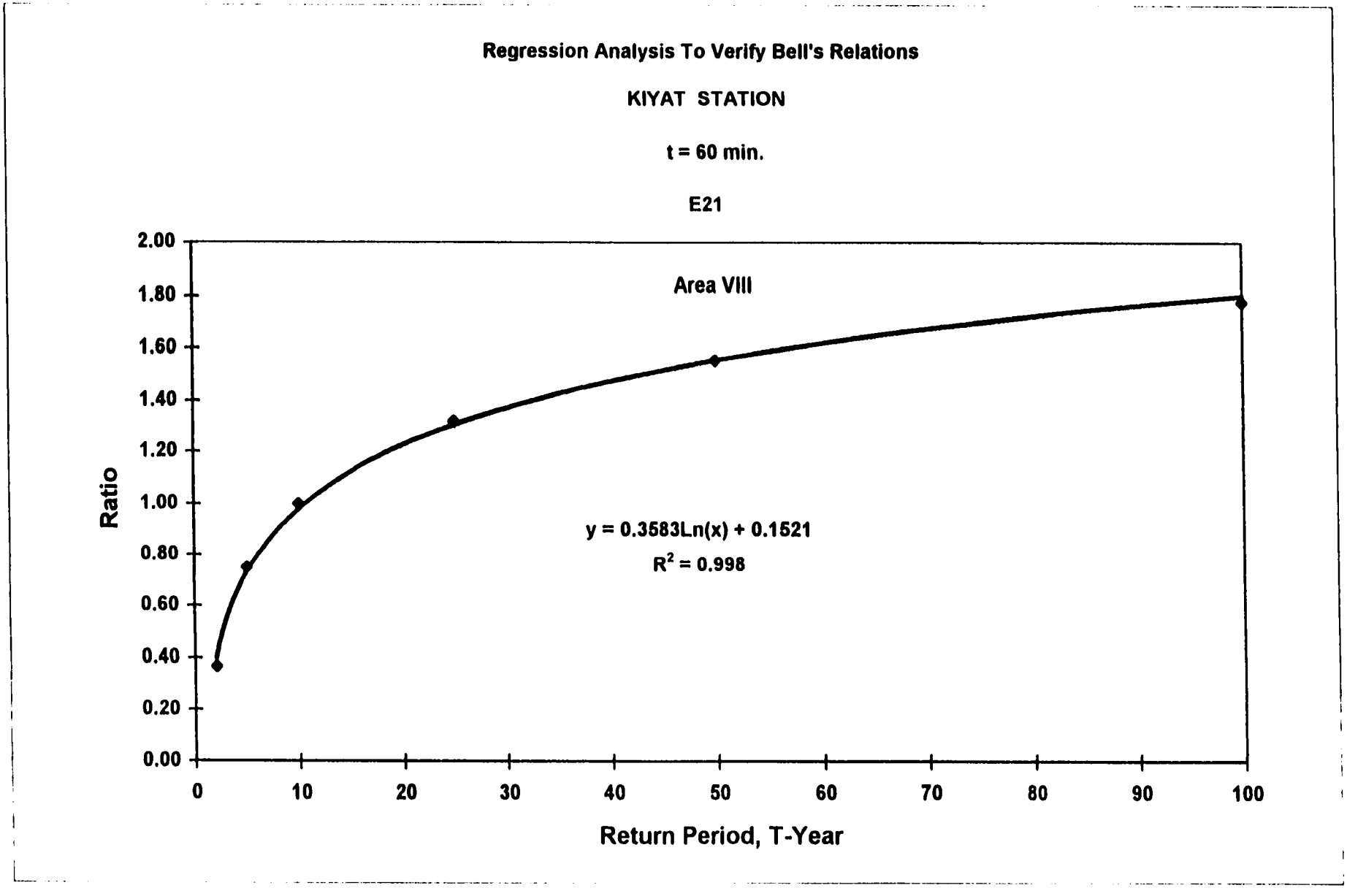

Regression Analysis To Verify Bell's Relations
RIYADAH STATION
t = 60 min.
E16
Area V
y = 0.307Ln(x) + 0.2742
R2 = 0.9984
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100


Regression Analysis To Verify Bell's Relations
SUWADRAH STATION
t = 60 min.
E17
Area VI
y = 0.3479Ln(x) + 0.1792
R2 = 0.9987
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100


Regression Analysis To Verify Bell's Relations
AL MEDINA FARM STATION
t = 60 min.
E18
Area VI
y = 0.334Ln(x) + 0.2104
R2 = 0.9984
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100


Regression Analysis To Verify Bell's Relations
KWASH STATION
t = 60 min.
E19
Area VI
y = 0.2113Ln(x) + 0.499
R2 = 0.9974
Ratio
Return Period, T-Year
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100


Regression Analysis To Verify Bell's Relations
KHUBAH STATION
t = 60 min.
E20
Area VI
y = 0.2708Ln(x) + 0.3596
R² = 0.9982
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

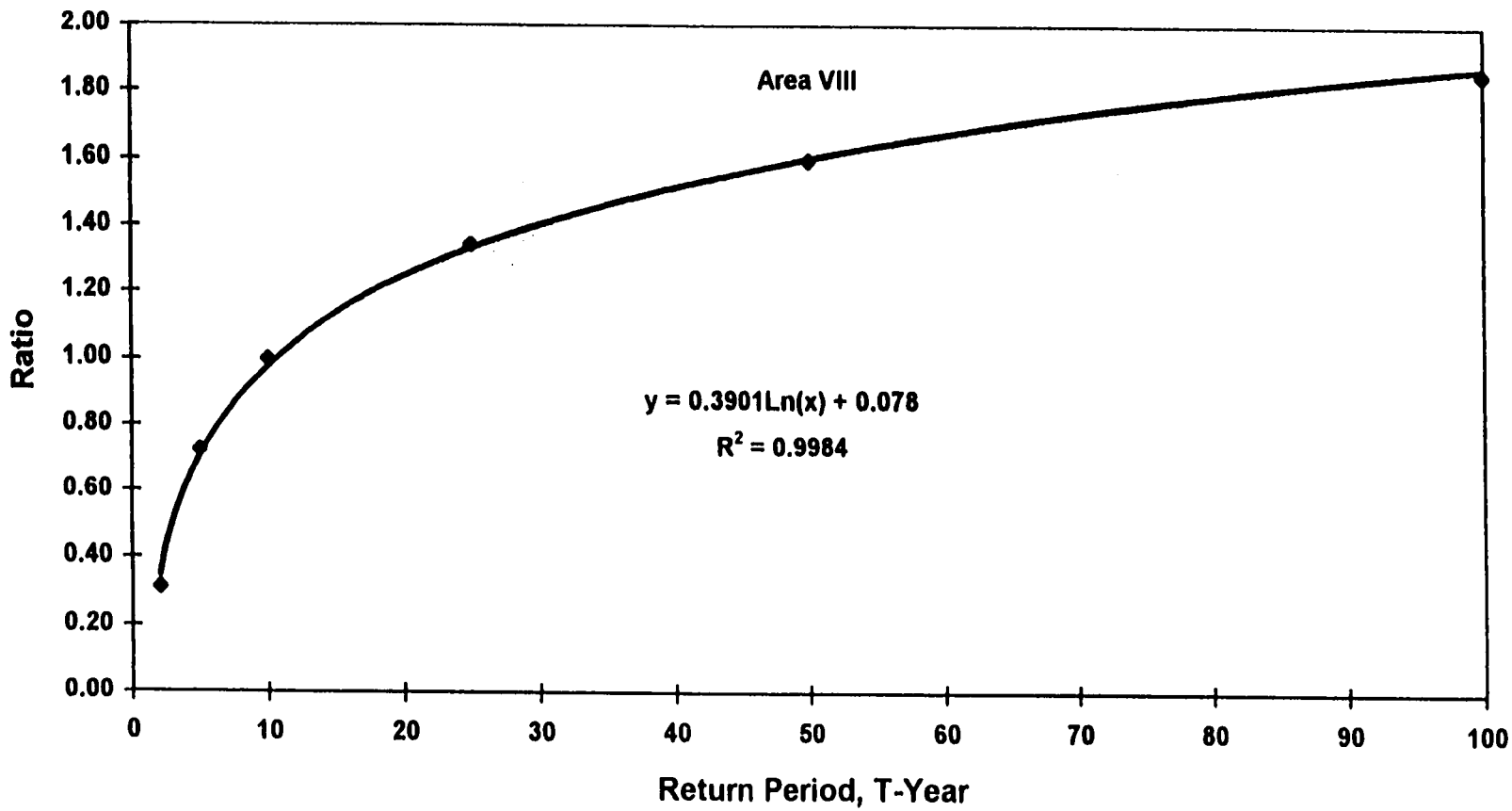

Regression Analysis To Verify Bell's Relations
KIYAT STATION
t = 60 min.
E21
Area VIII
y = 0.3583Ln(x) + 0.1521
R2 = 0.998
Ratio
Return Period, T-Year
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

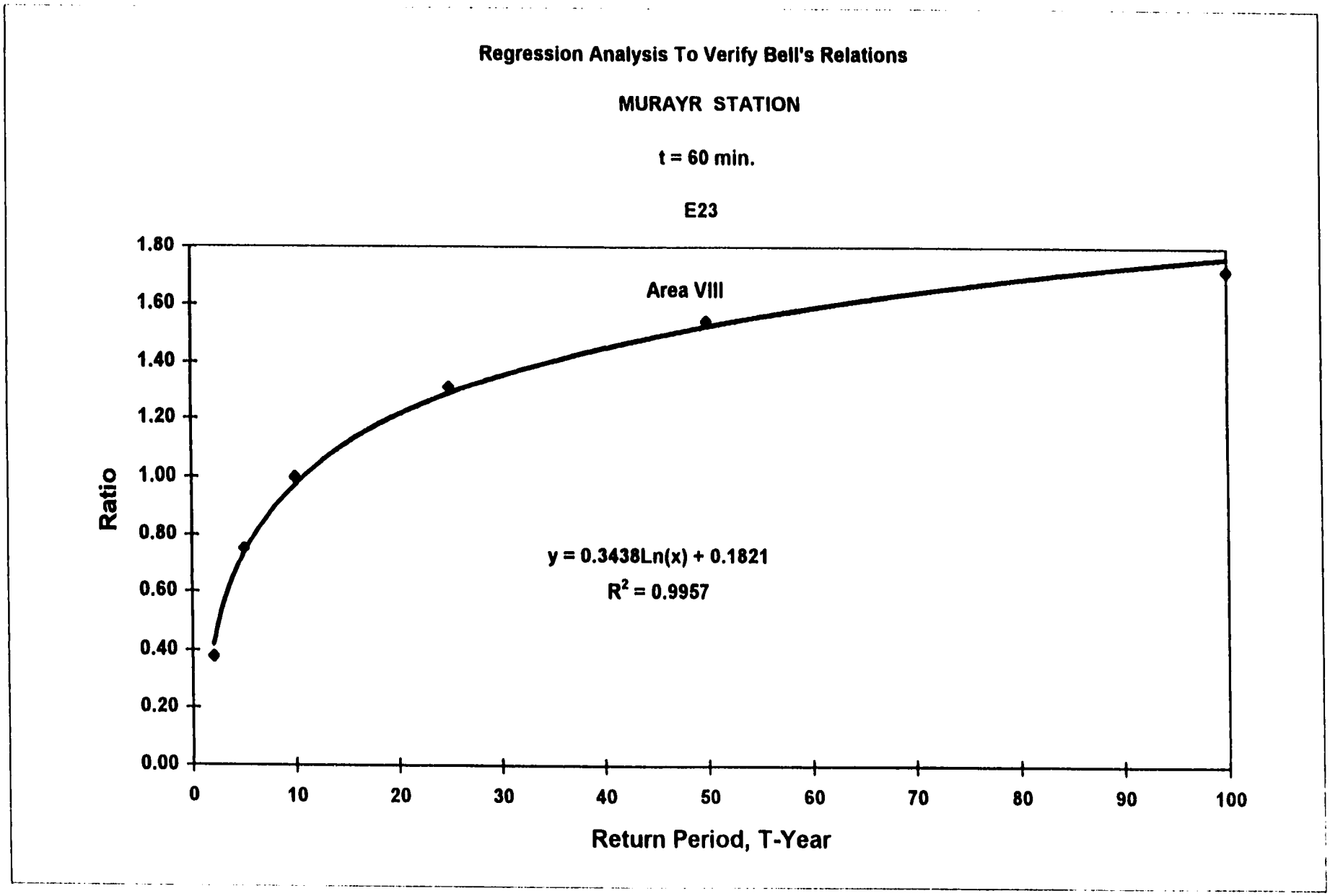
Regression Analysis To Verify Bell's Relations

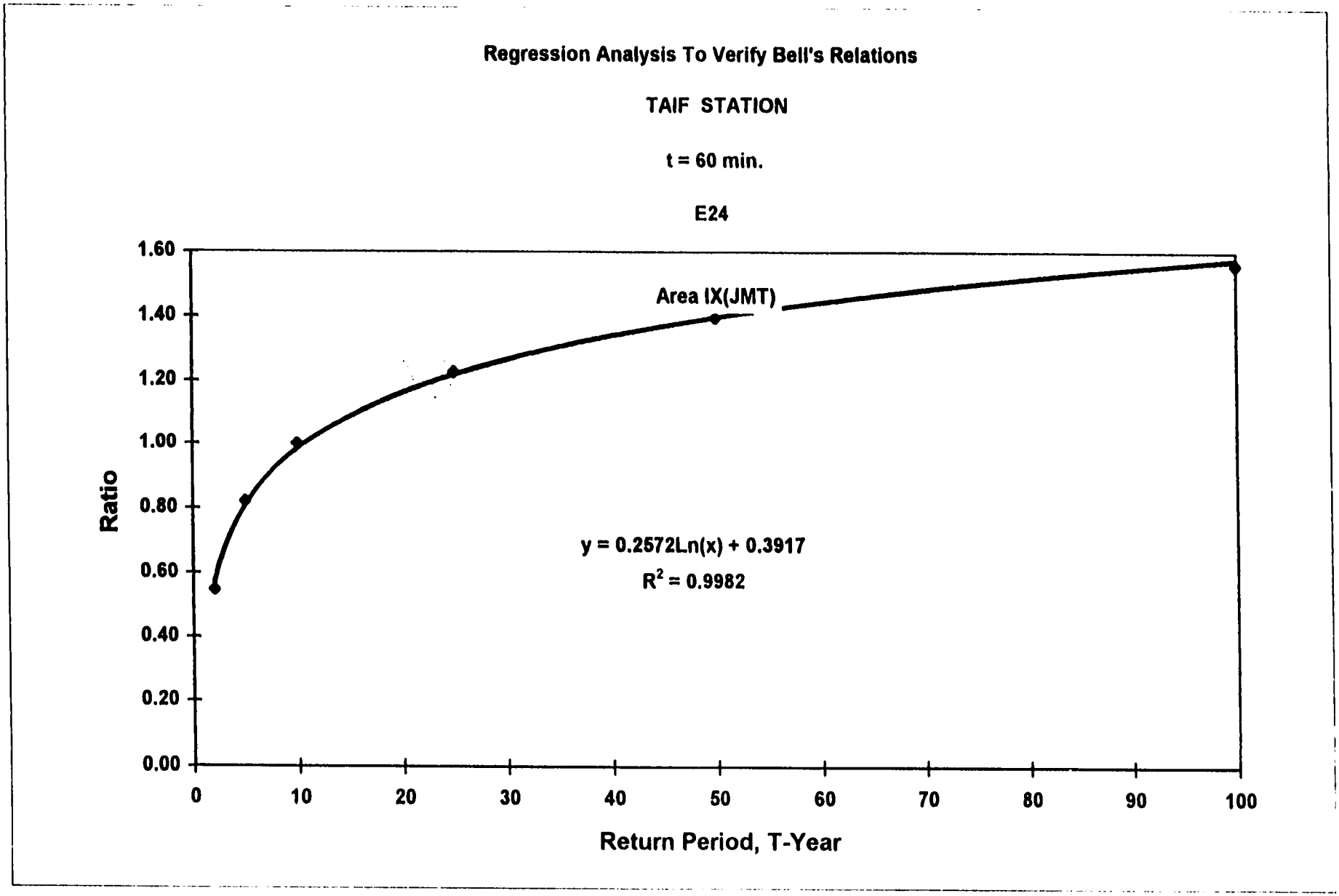
HANAKIYAH STATION

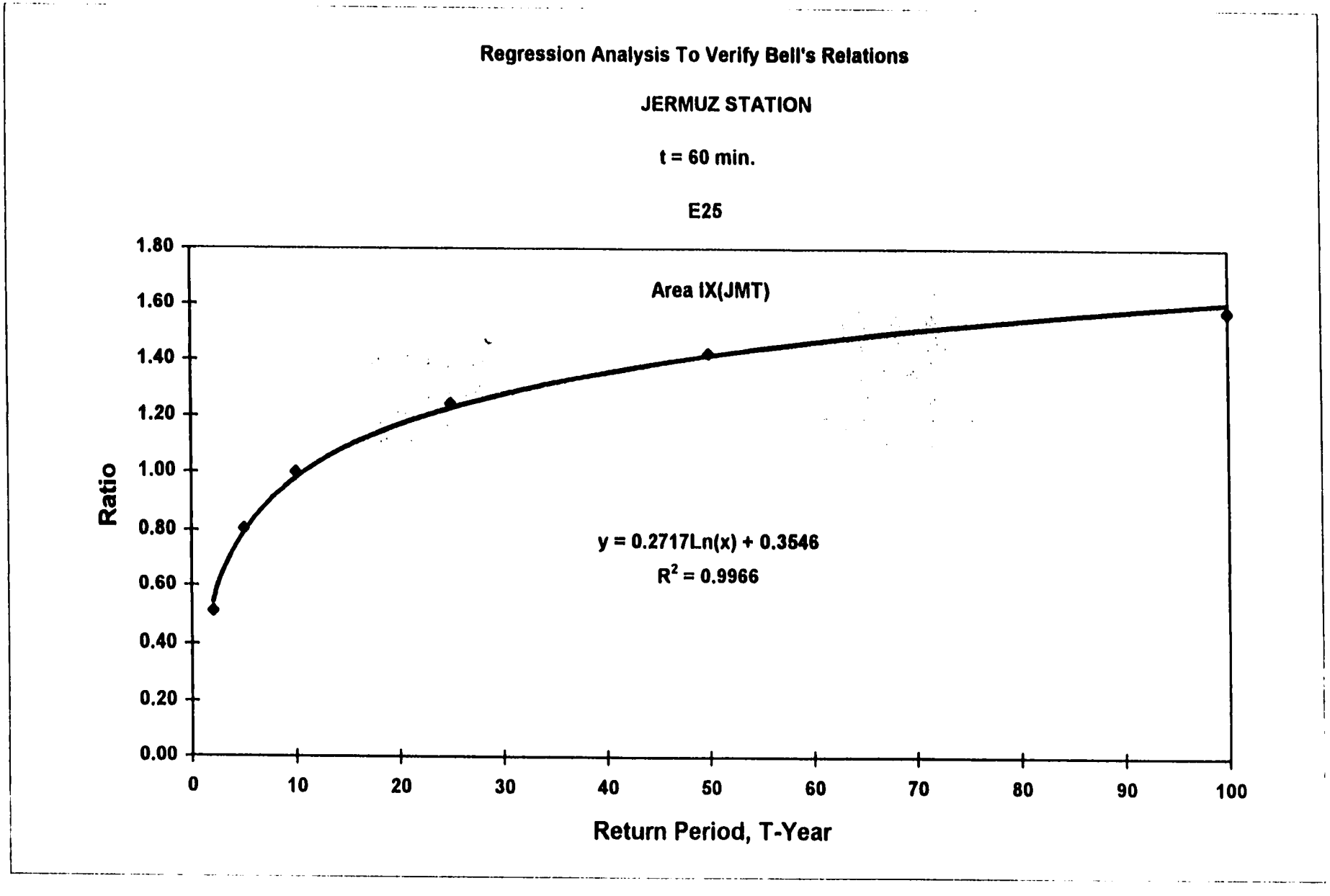
t = 60 min.

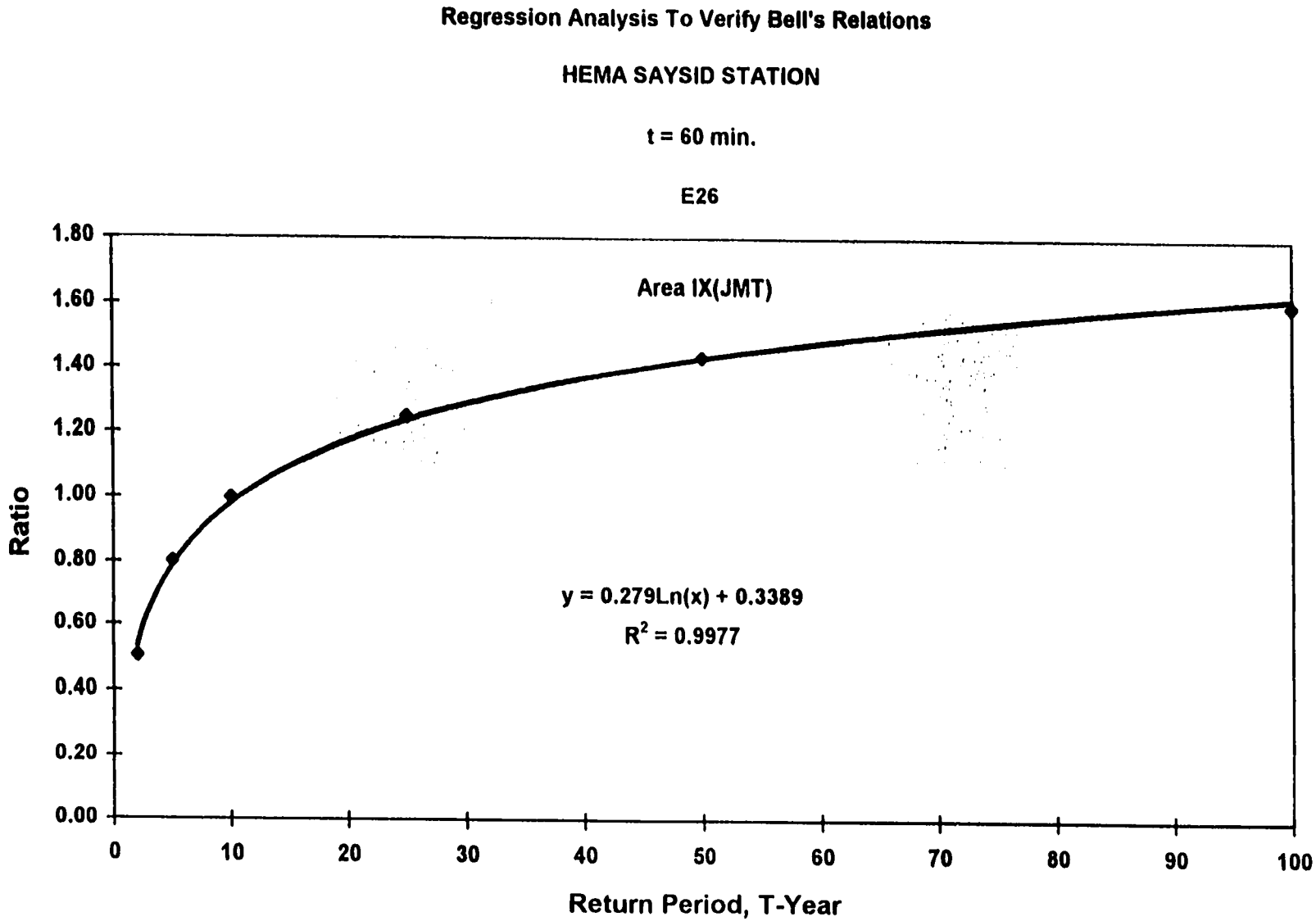
E22




Regression Analysis To Verify Bell's Relations
MURAYR STATION
t = 60 min.
E23
Area VIII
y = 0.3438Ln(x) + 0.1821
R2 = 0.9957
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100


Regression Analysis To Verify Bell's Relations
TAIF STATION
t = 60 min.
E24
Area IX(JMT)
y = 0.2572Ln(x) + 0.3917
R2 = 0.9982
Ratio
Return Period, T-Year
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100


Regression Analysis To Verify Bell's Relations
JERMUZ STATION
t = 60 min.
E25
Area IX(JMT)
y = 0.2717Ln(x) + 0.3546
R2 = 0.9966
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

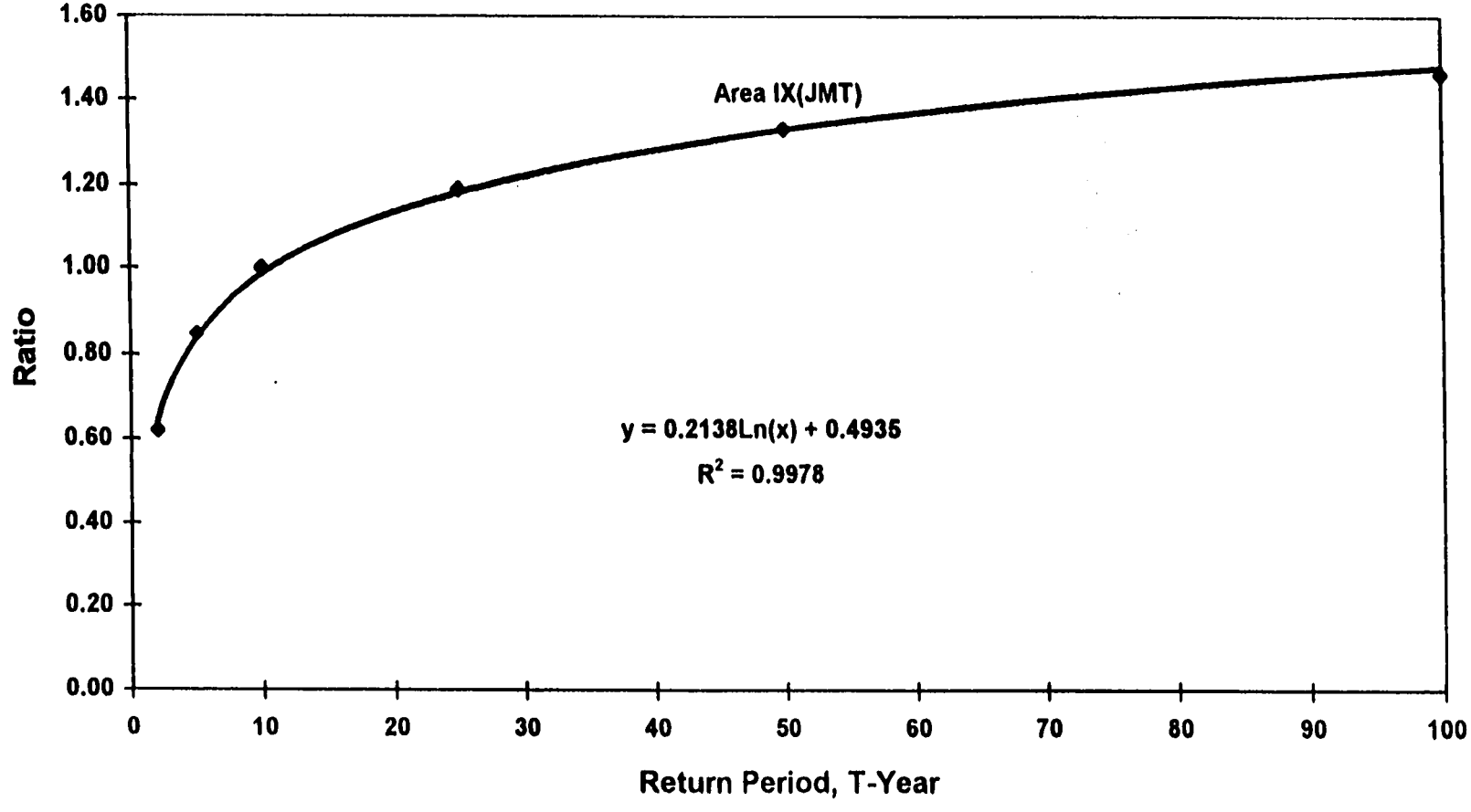

Regression Analysis To Verify Bell's Relations
HEMA SAYSID STATION
t = 60 min.
E26
Area IX(JMT)
y = 0.279Ln(x) + 0.3389
R2 = 0.9977
Ratio
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100
Return Period, T-Year

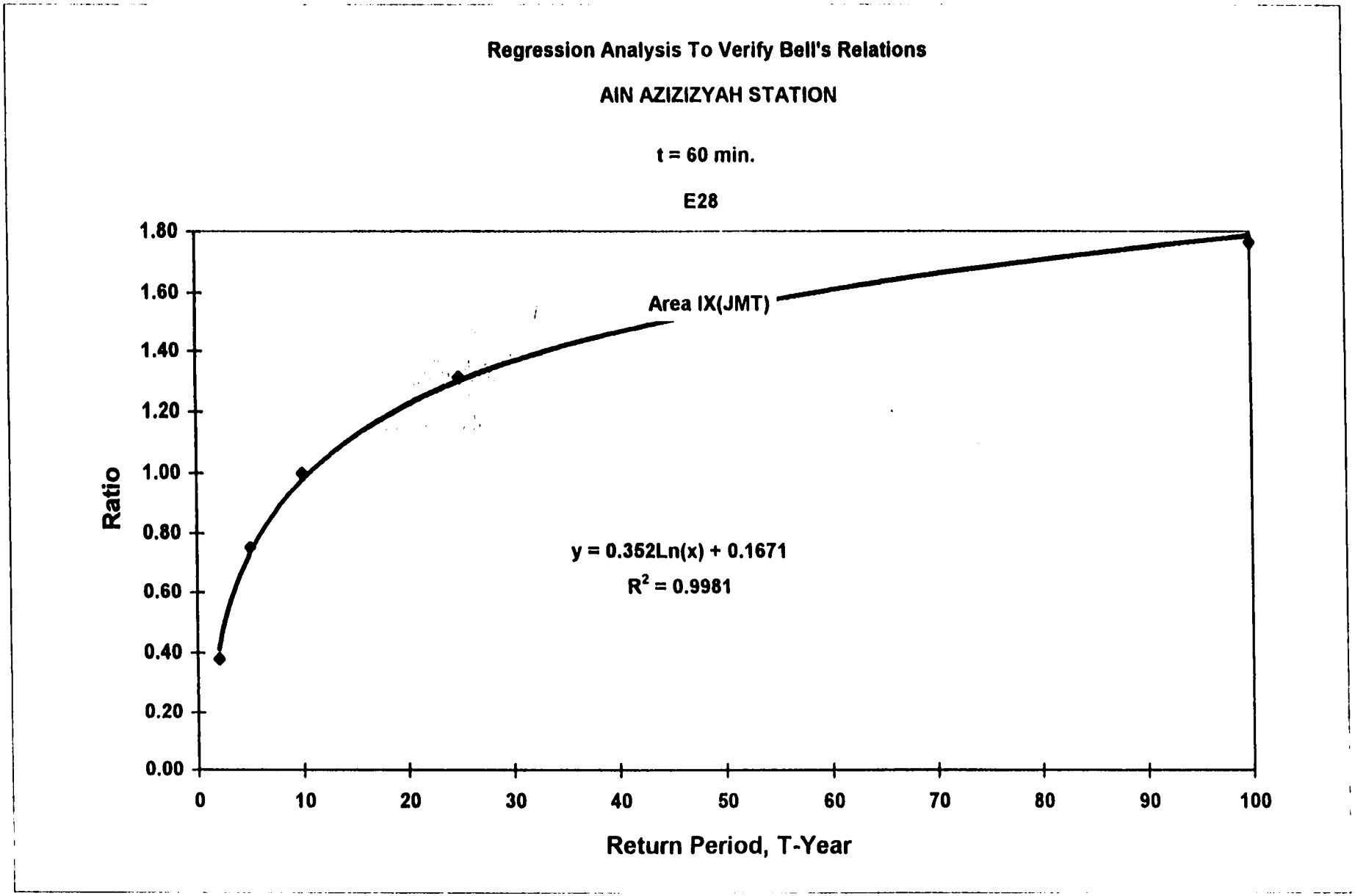
Regression Analysis To Verify Bell's Relations

WADI DAHIYAH STATION

t = 60 min.

E27




Regression Analysis To Verify Bell's Relations
AIN AZIZIZYAH STATION
t = 60 min.
E28
Area IX(JMT)
y = 0.352Ln(x) + 0.1671
R2 = 0.9981
Ratio
Return Period, T-Year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

APPENDIX F

F_1 - F_8

AVERAGE RAINFALL DATA & INTENSITY / DURATION DATA TABLES

Average Rainfall Depth (mm)

F1

Region: I

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.48430

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.90430

S. NO.	Duration (min.)			
	10	30	60	120
1	0.50	0.50	2.70	5.80
2	0.50	1.50	7.90	10.30
3	1.90	3.10	3.20	5.40
4	3.90	5.40	5.60	6.50
5	7.80	8.70	8.70	9.80
6	4.80	7.50	8.70	9.80
7	6.90	7.90	9.20	9.50

Average Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
50	89.30	34.69	16.90	8.14
25	75.56	29.58	14.79	7.30
10	57.04	22.70	11.92	6.18
5	42.38	17.26	9.65	5.29
2	20.24	9.03	6.21	3.94

Average Rainfall Depth (mm)

F2

Region: II

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.48430

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.90430

S. NO.	Duration (min.)			
	10	30	60	120
1	6.50	7.20	7.40	7.60
2	4.10	5.40	7.40	9.10
3	10.40	18.40	18.60	19.90
4	4.70	7.70	9.50	10.60
5	9.00	15.10	18.70	20.30
6	7.00	9.30	9.80	10.80

Average Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
50	96.77	59.54	32.03	17.08
25	85.44	51.61	27.88	14.90
10	70.16	40.93	22.30	11.98
5	58.07	32.48	17.88	9.66
2	39.80	19.71	11.21	6.16

Average Rainfall Depth (mm)

F3

Region: III

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.48430

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.90430

S. NO.	Duration (min.)			
	10	30	60	120
1	8.00	12.00	14.50	21.40
2	7.40	15.70	21.40	31.40
3	7.70	10.60	12.90	16.00
4	12.70	20.40	23.20	26.40
5	19.10	21.60	25.80	31.00
6	15.10	25.40	31.40	36.90
7	16.20	32.60	38.70	40.60
8	8.40	13.40	16.40	18.50

Average Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
50	174.69	94.81	56.39	30.46
25	153.34	83.10	49.53	27.05
10	124.56	67.32	40.27	22.45
5	101.78	54.83	32.95	18.81
2	67.37	35.96	21.89	13.32

Average Rainfall Depth (mm)

F4

Region: IV

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.48430

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.90430

S. NO.	Duration (min.)			
	10	30	60	120
1	2.30	5.10	6.80	8.00
2	5.80	9.40	12.40	16.30
3	3.60	4.80	5.80	7.90
4	5.50	7.80	10.80	12.50
5	3.70	5.30	6.70	8.30
6	2.90	4.70	5.50	8.80
7	5.50	6.50	7.30	7.60

Average Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
50	56.98	25.95	17.88	11.15.
25	50.42	23.17	15.83	9.87
10	41.58	19.43	13.06	8.16
5	34.58	16.47	10.87	6.80
2	24.02	11.99	7.56	4.74

Average Rainfall Depth (mm)

F5

Region: V

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49020

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.92880

S. NO.	Duration (min.)			
	10	30	60	120
1	4.60	7.30	8.90	12.00
2	2.20	2.90	3.70	5.90
3	5.10	7.90	10.60	10.90
4	5.10	5.90	8.10	9.80
5	7.10	9.90	12.30	16.70
6	6.40	7.90	8.30	25.60
7	3.50	5.10	6.00	7.10
8	5.20	6.30	6.80	7.40
9	3.30	4.70	6.30	7.90

Average Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
50	62.19	28.15	17.33	17.17
25	55.21	25.00	15.39	14.81
10	45.80	20.75	12.76	11.64
5	38.35	17.39	10.68	9.12
2	27.11	12.31	7.55	5.32

Average Rainfall Depth (mm)

F6

Region: VI

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.48430

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.90430

S. NO.	Duration (min.)			
	10	30	60	120
1	13.80	19.40	22.00	22.00
2	12.50	17.10	18.60	21.40
3	6.50	11.30	15.40	16.50
4	9.60	15.90	20.70	21.20
5	10.00	18.50	22.20	22.60
6	12.10	24.50	37.90	40.60
7	7.70	16.00	17.40	17.50

Average Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
50	121.96	65.45	50.09	26.78
25	109.59	59.20	44.32	23.64
10	92.93	50.76	36.53	19.42
5	79.74	44.09	30.37	16.08
2	59.82	34.01	21.06	11.03

Average Rainfall Depth (mm)

F7

Region: VIII

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49520

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.94970

S. NO.	Duration (min.)			
	10	30	60	120
1	2.80	5.60	8.60	10.60
2	5.90	6.90	6.90	7.40
3	8.80	12.30	13.10	13.10
4	6.60	14.10	20.00	20.30
5	3.00	6.60	8.70	10.70
6	5.70	7.90	9.30	11.50
7	7.20	10.50	15.60	23.30
8	3.10	3.30	3.50	3.90
9	6.20	8.30	8.30	9.40
10	7.70	14.90	17.80	18.80

Average Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

Return period Years	Duration (min.)			
	10	30	60	120
50	79.24	45.33	29.96	17.37
25	69.94	39.71	26.09	15.11
10	57.41	32.12	20.86	12.07
5	47.48	26.12	16.72	9.67
2	32.50	17.05	10.47	6.04

Average Rainfall Depth (mm)

F8

Region: IX(JMT)

THEORETICAL VALUE OF REDUCED VARIATE CORRECTION 0.49520

CORRECTION OF SLOPE TO GUMBEL LINE SIGMAN 0.94970

S. NO.	Duration (min.)			
	10	30	60	120
1	12.10	13.40	24.20	28.50
2	16.80	28.70	35.40	37.00
3	9.80	17.30	23.20	23.20
4	11.50	19.20	21.80	24.90
5	10.30	16.70	20.40	21.50
6	9.50	17.70	25.00	26.50
7	11.80	25.80	34.70	40.70
8	8.20	17.10	19.40	20.80
9	6.60	9.10	10.80	13.70

Average Rainfall Intensity (mm/hr) From Gumbel 2 Program

(IDF Tables)

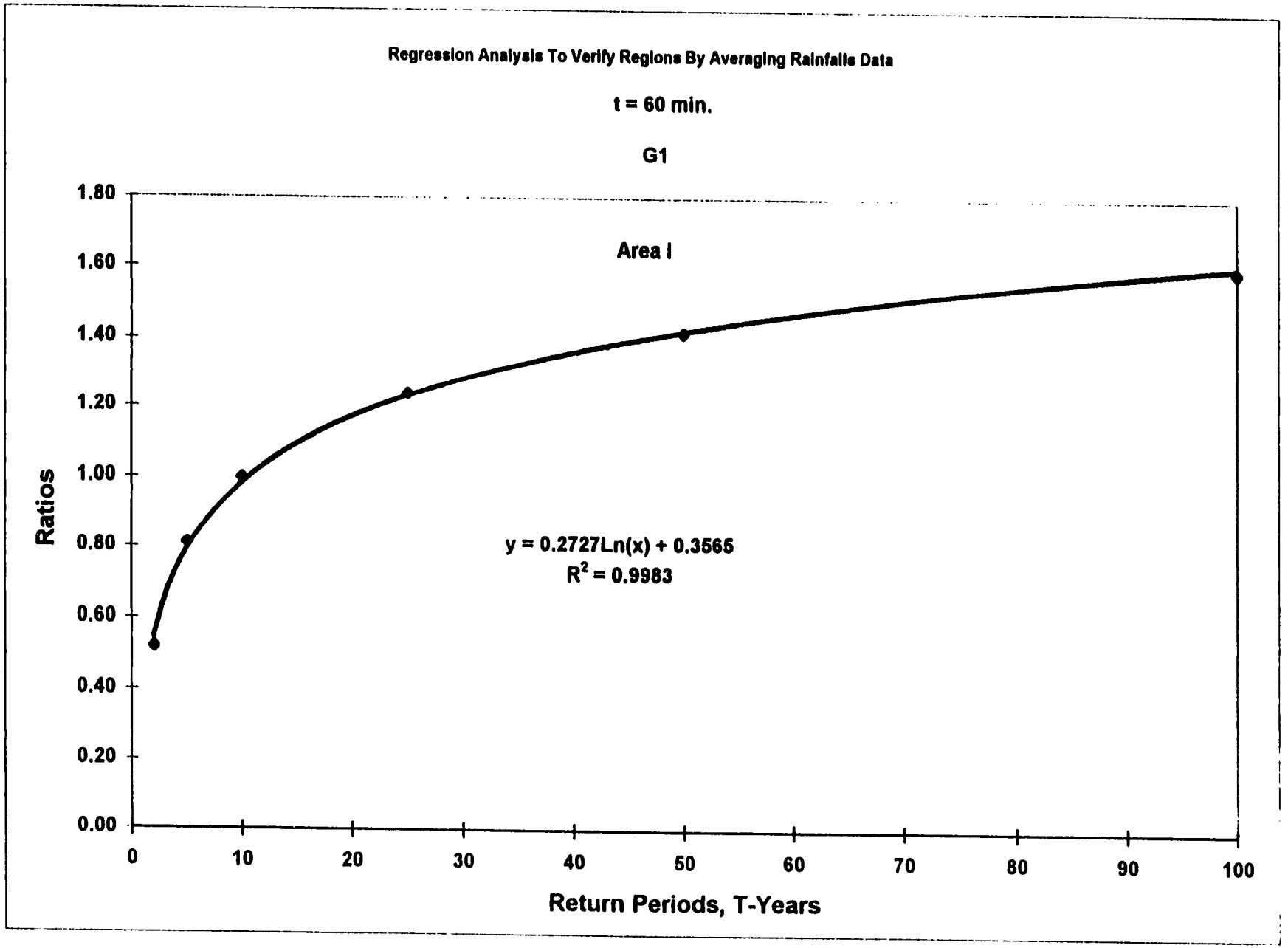
Return period Years	Duration (min.)			
	10	30	60	120
50	127.93	80.07	51.71	28.50
25	114.84	71.12	45.97	25.34
10	97.18	59.06	38.24	21.08
5	83.20	49.51	32.11	17.71
2	62.10	35.09	22.87	12.62

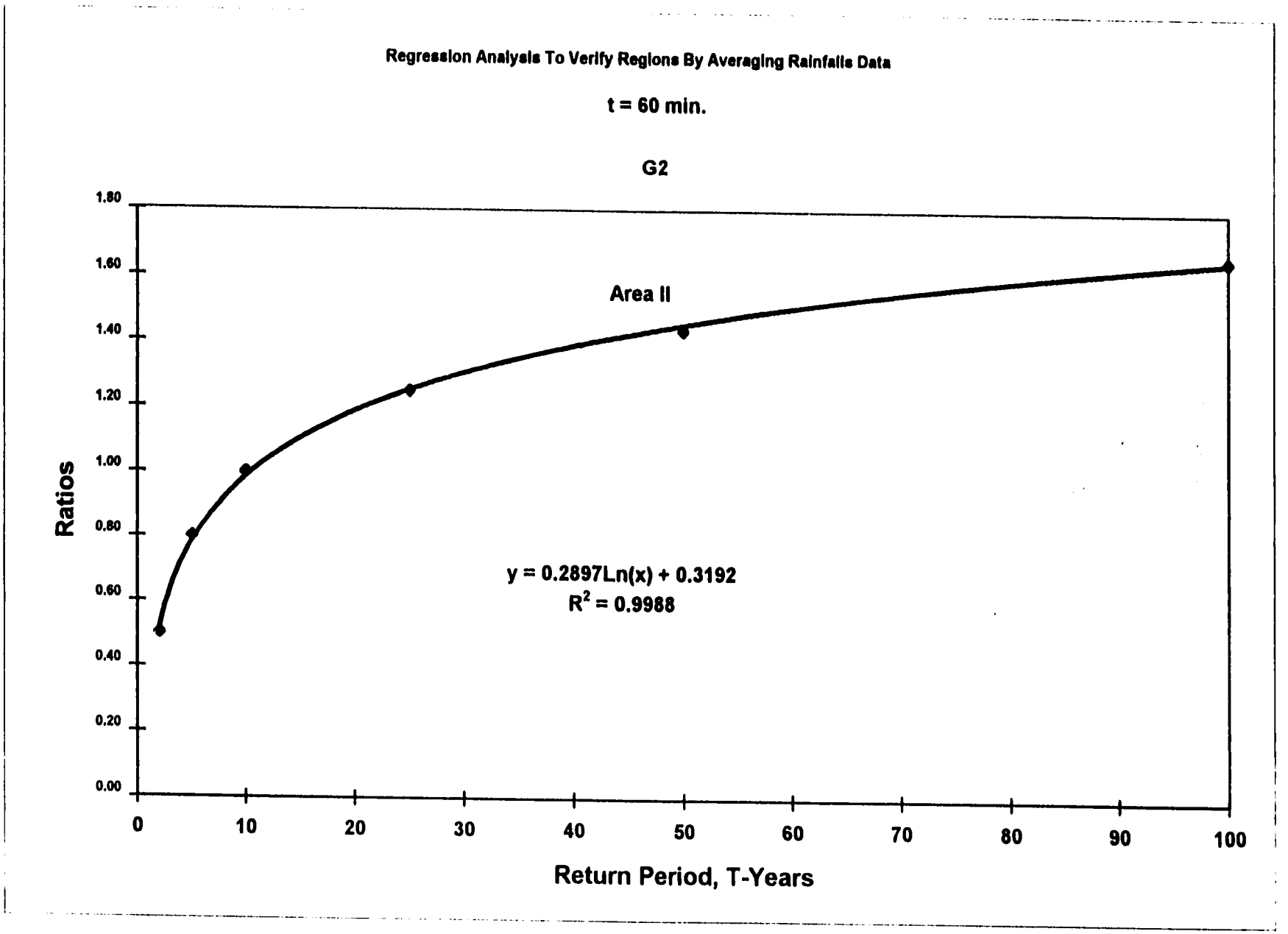
APPENDIX G

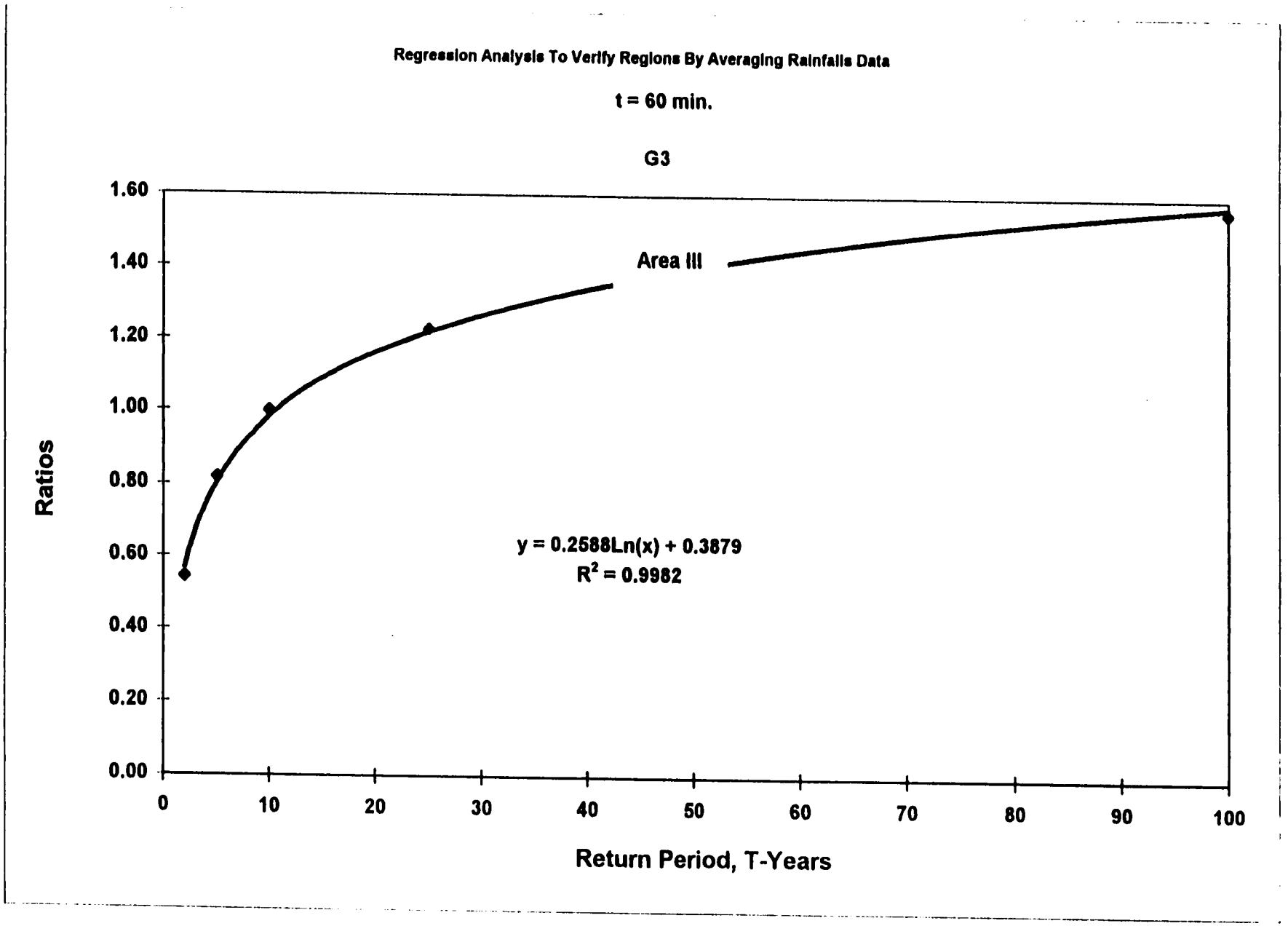
G_1 - G_8

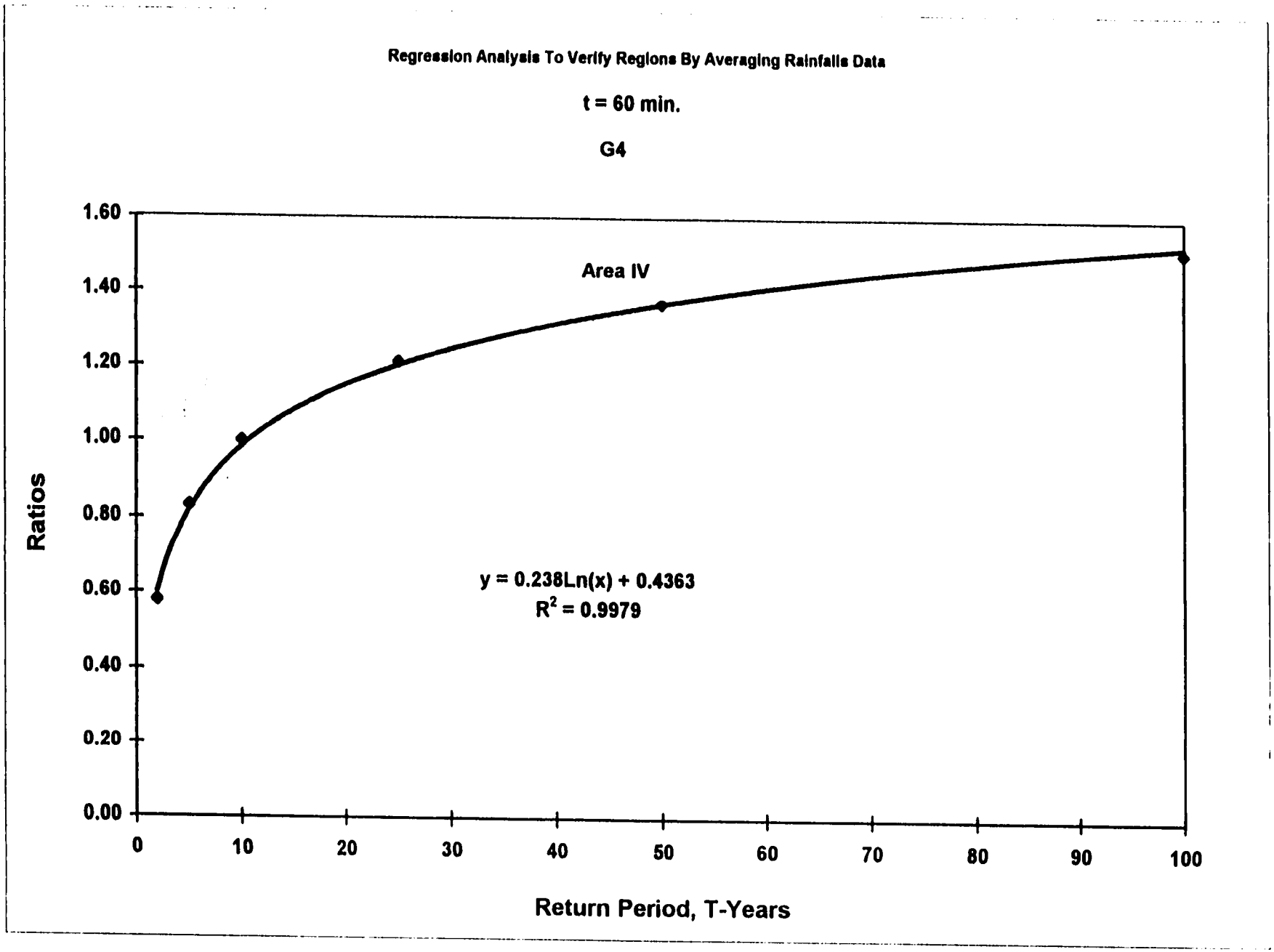
$$\frac{P_T^t}{P_{10}^T}$$

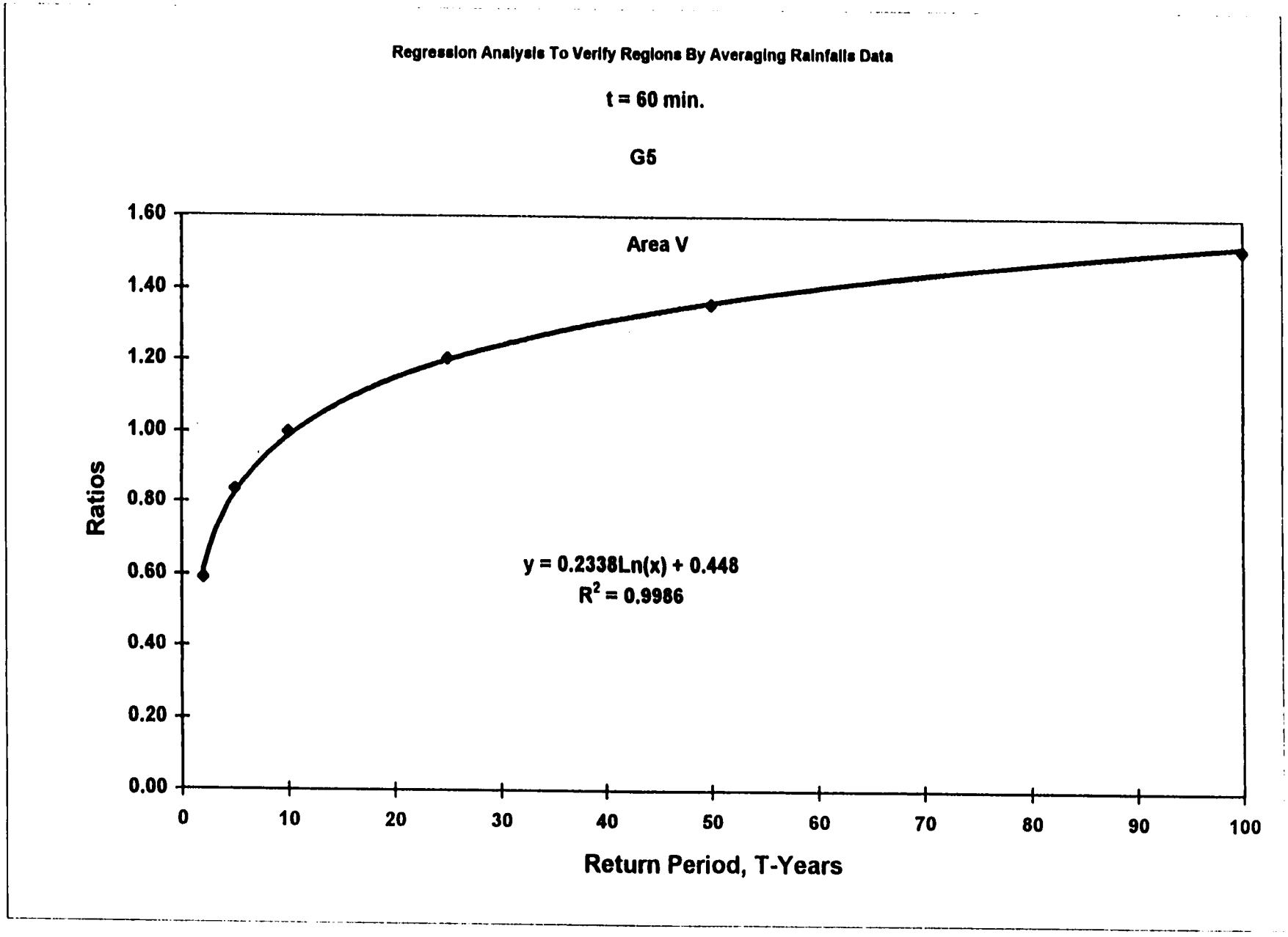
MODEL CURVES FOR AVERAGE RAINFALL DATA BY REGION


Regression Analysis To Verify Regions By Averaging Rainfalls Data
t = 60 min.
G1
Area I
y = 0.2727Ln(x) + 0.3565
R2 = 0.9983
Ratios
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100
Return Periods, T-Years


Regression Analysis To Verify Regions By Averaging Rainfalls Data
t = 60 min.
G2
Area II
y = 0.2897Ln(x) + 0.3192
R2 = 0.9988
Ratios
Return Period, T-Years
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100


Regression Analysis To Verify Regions By Averaging Rainfalls Data
t = 60 min.
G3
Area III
y = 0.2588Ln(x) + 0.3879
R2 = 0.9982
Ratios
Return Period, T-Years
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

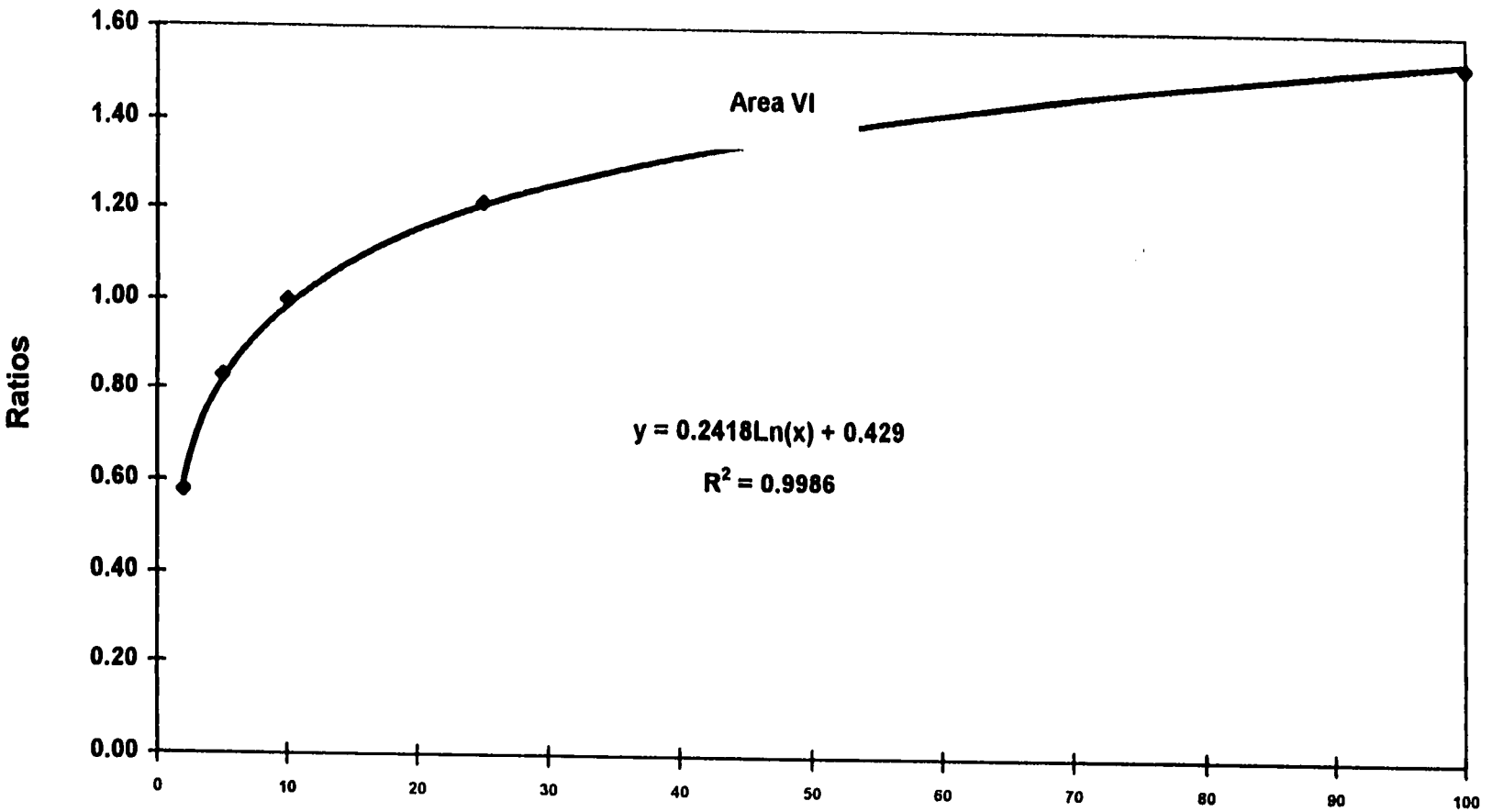

Regression Analysis To Verify Regions By Averaging Rainfalls Data
t = 60 min.
G4
Area IV
y = 0.238Ln(x) + 0.4363
R2 = 0.9979
Ratios
Return Period, T-Years
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

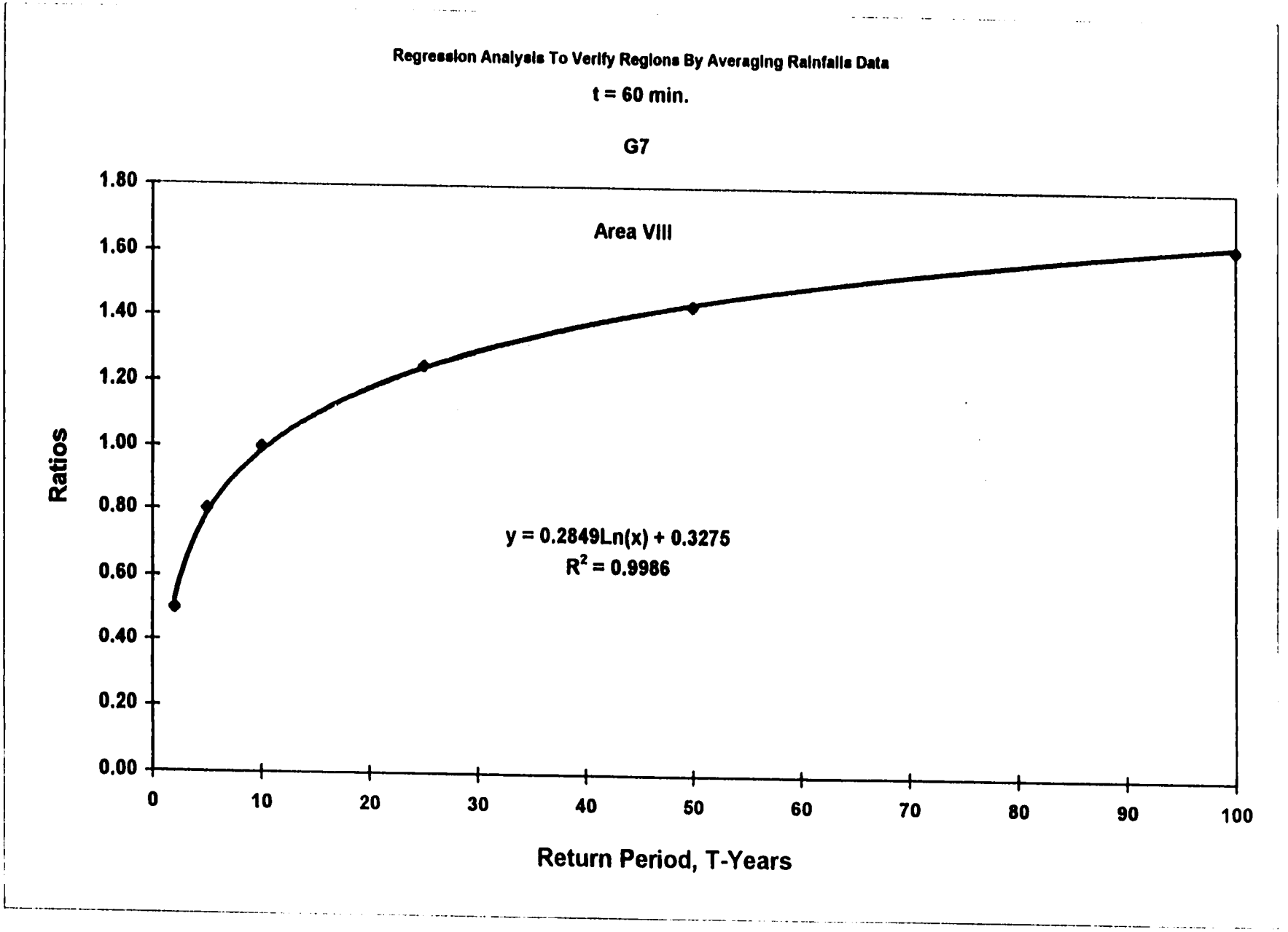

Regression Analysis To Verify Regions By Averaging Rainfalls Data
t = 60 min.
G5
Area V
y = 0.2338Ln(x) + 0.448
R2 = 0.9986
Ratios
Return Period, T-Years
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

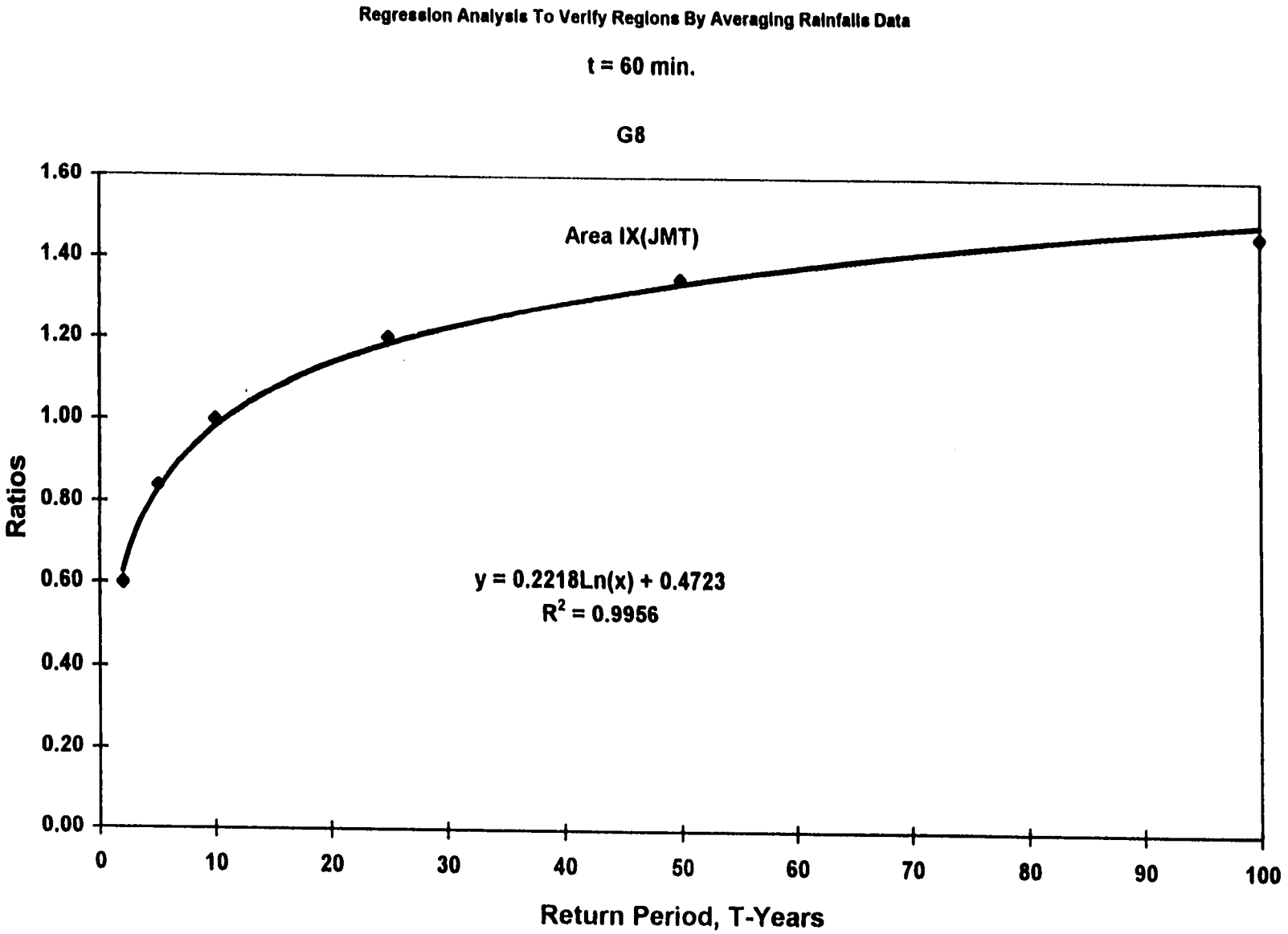
Regression Analysis To Verify Regions By Averaging Rainfalls Data

t = 60 min.

G6




Regression Analysis To Verify Regions By Averaging Rainfalls Data
t = 60 min.
G7
Area VIII
y = 0.2849Ln(x) + 0.3275
R2 = 0.9986
Ratios
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100
Return Period, T-Years


Regression Analysis To Verify Regions By Averaging Rainfalls Data
t = 60 min.
G8
Area IX(JMT)
y = 0.2218Ln(x) + 0.4723
R2 = 0.9956
Ratios
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100
Return Period, T-Years

APPENDIX H

H_1 - H_8

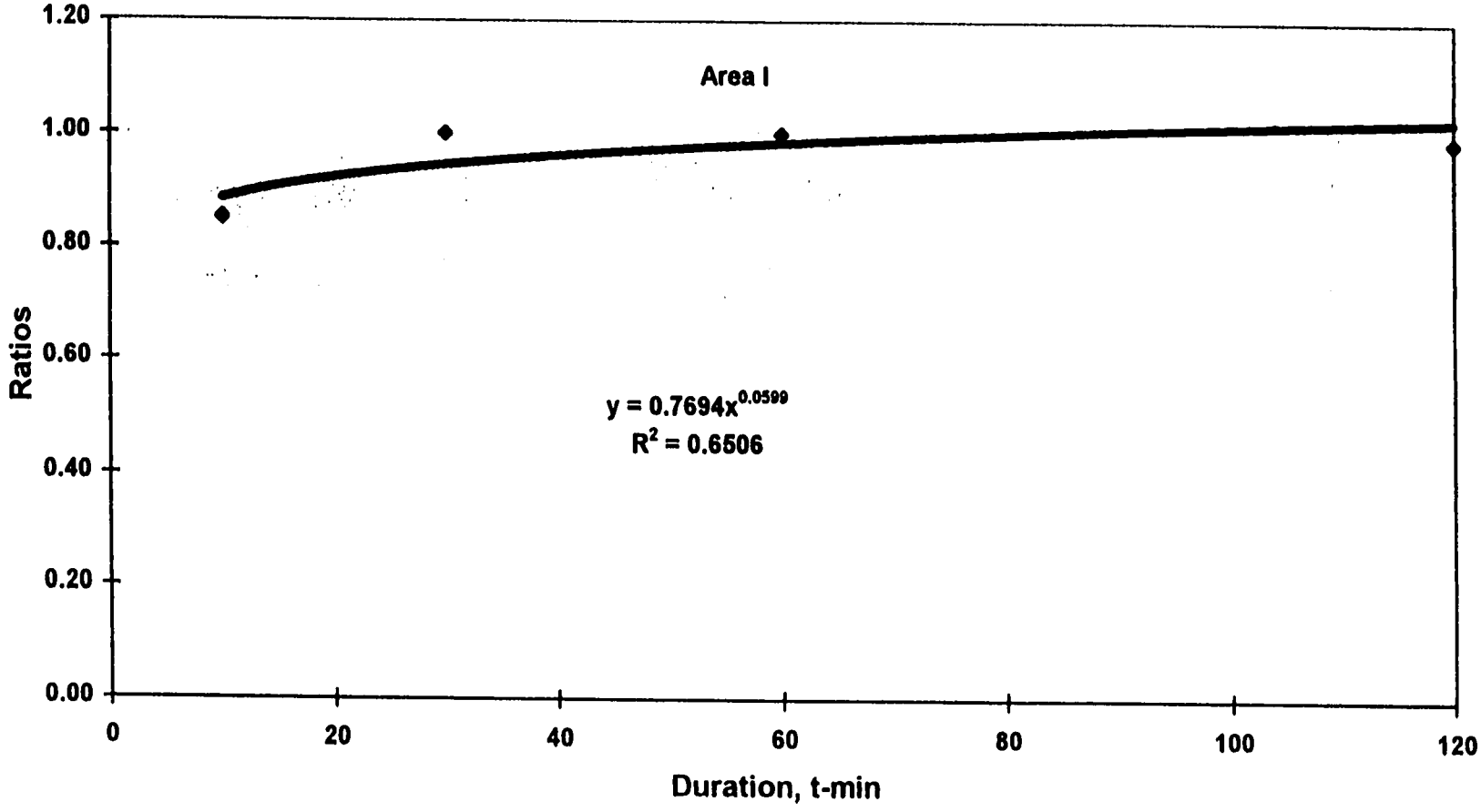
$$\frac{P_T^t}{P_T^{60}}$$

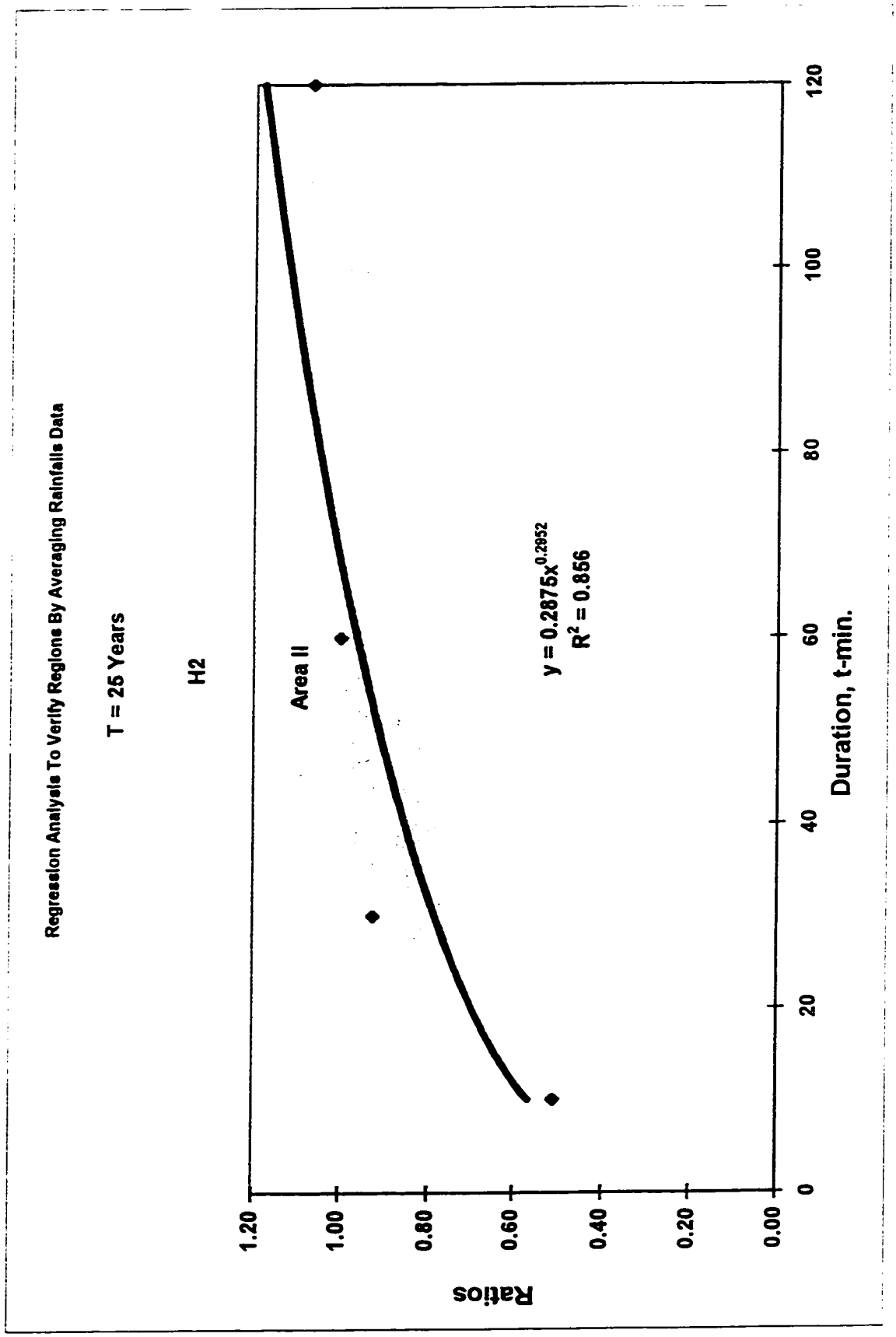
MODEL CURVES FOR AVERAGE RAINFALL DATA BY REGION

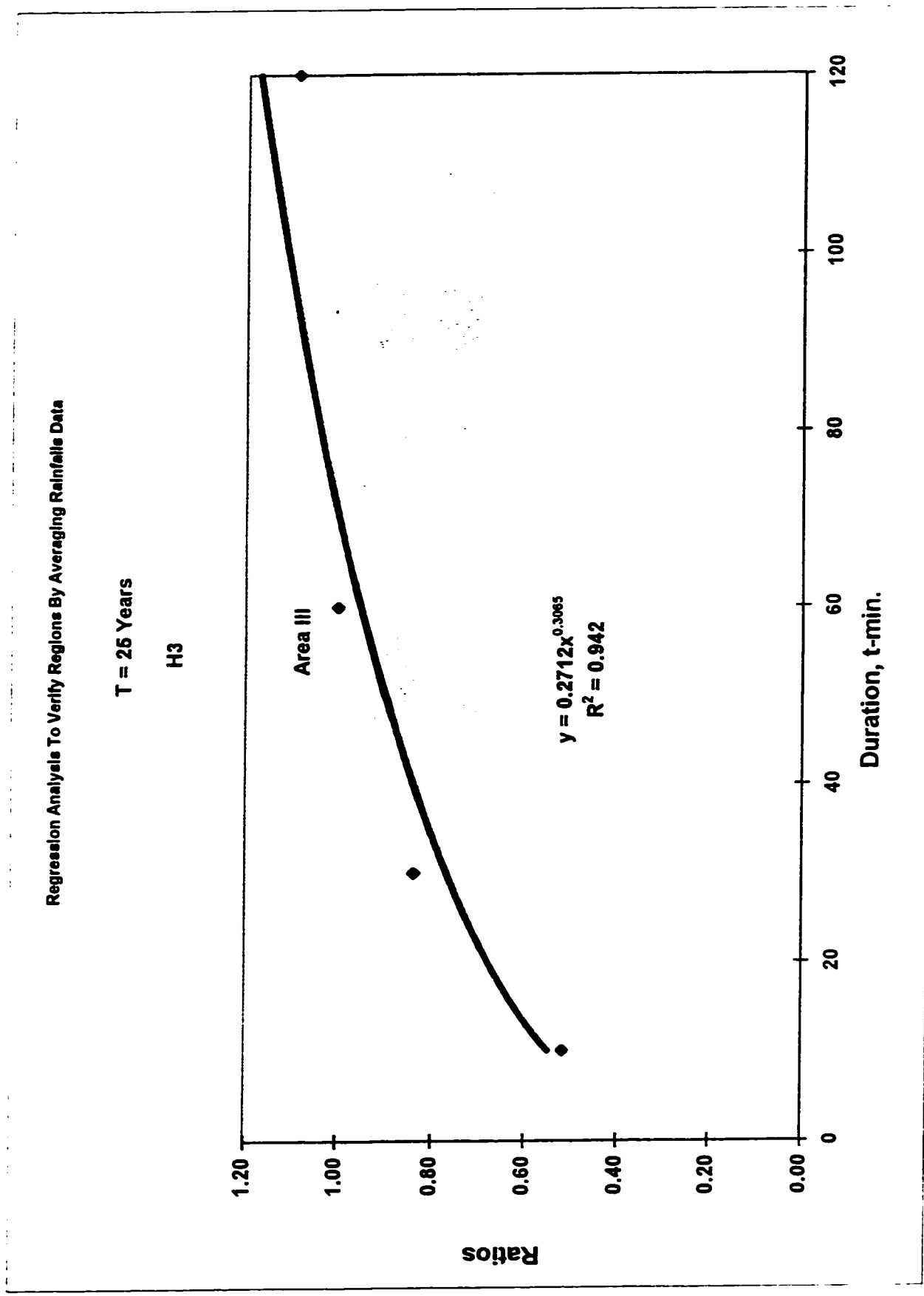
Regression Analysis To Verify Regions By Averaging Rainfalls Data

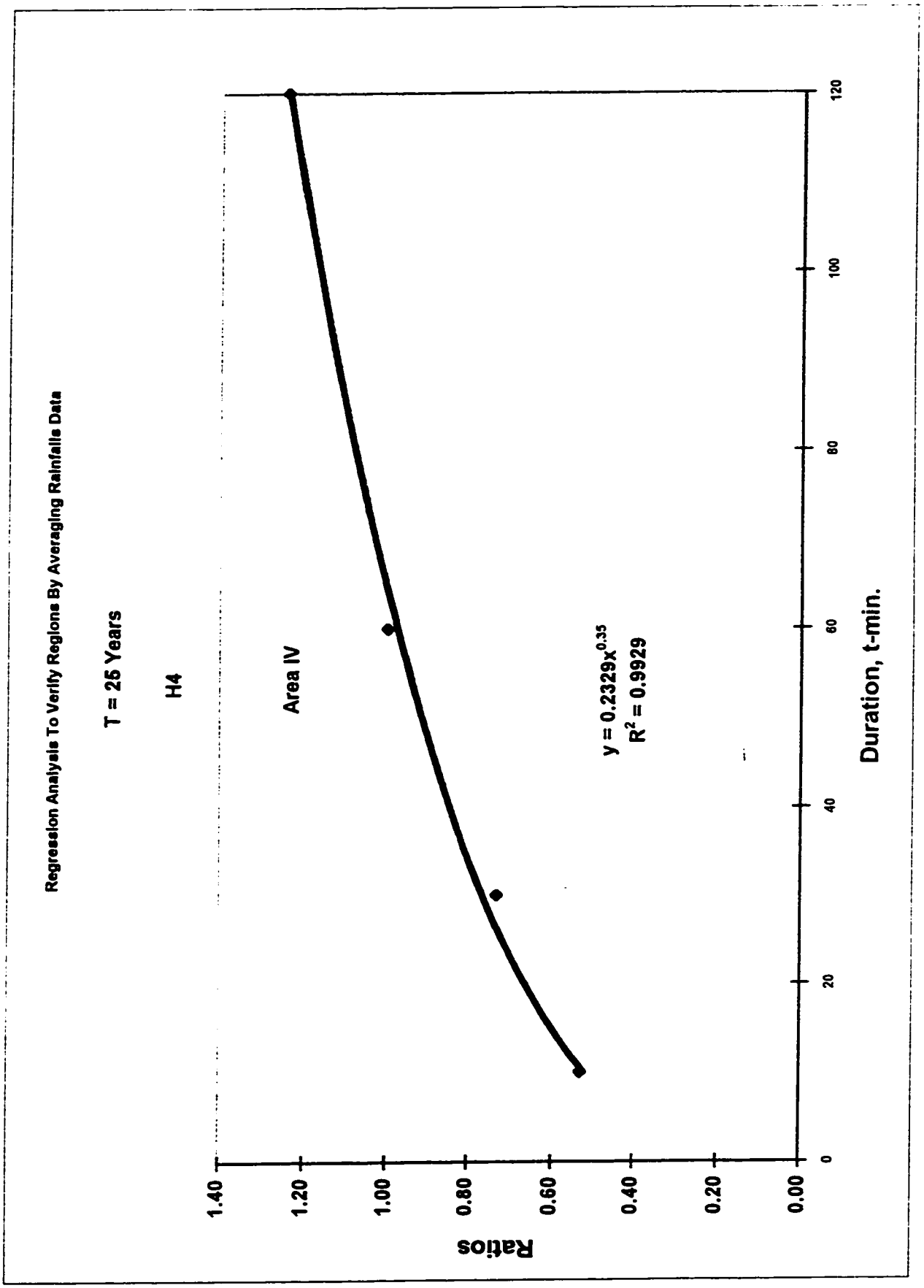
T = 25 Years

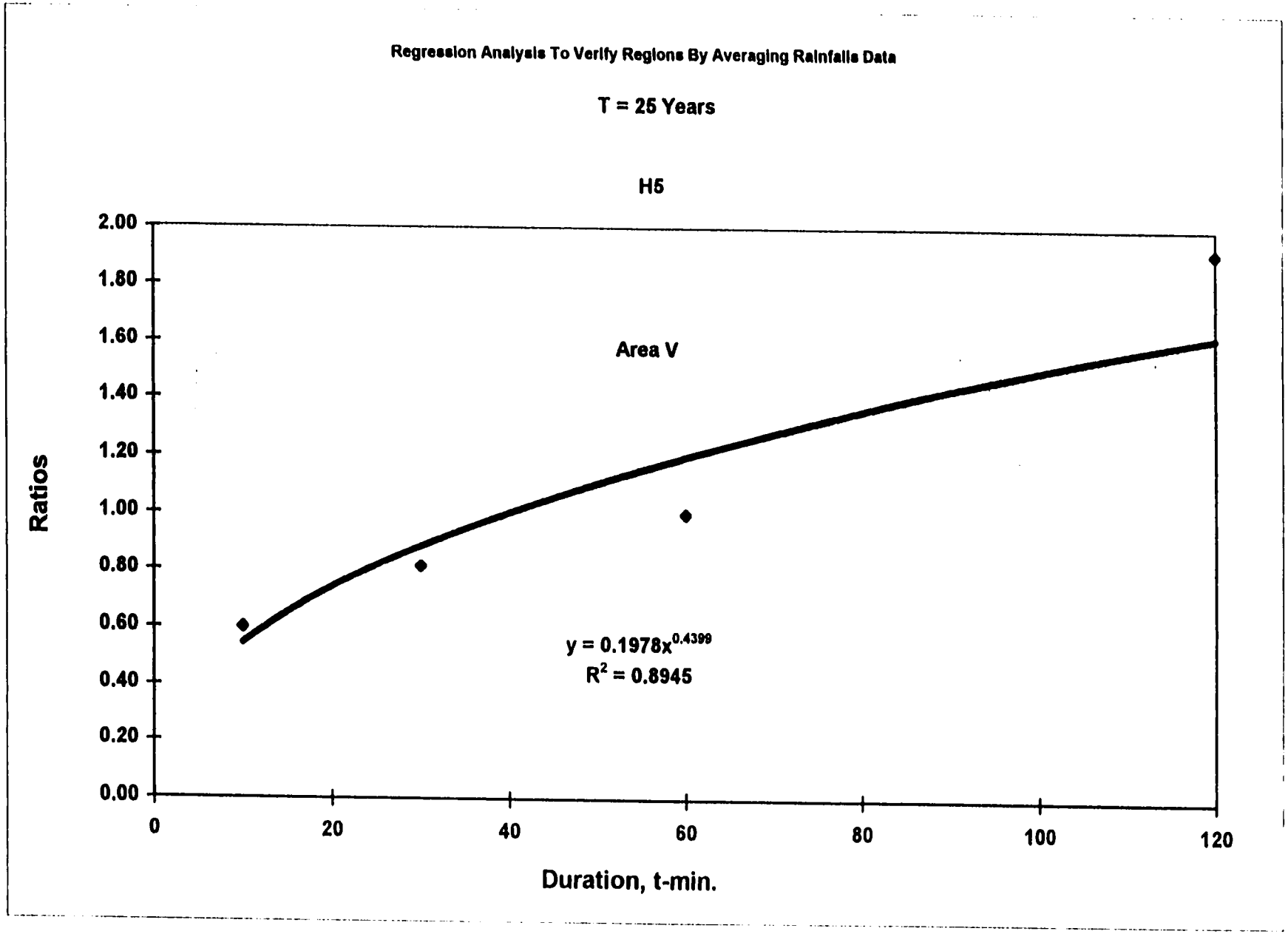
H1

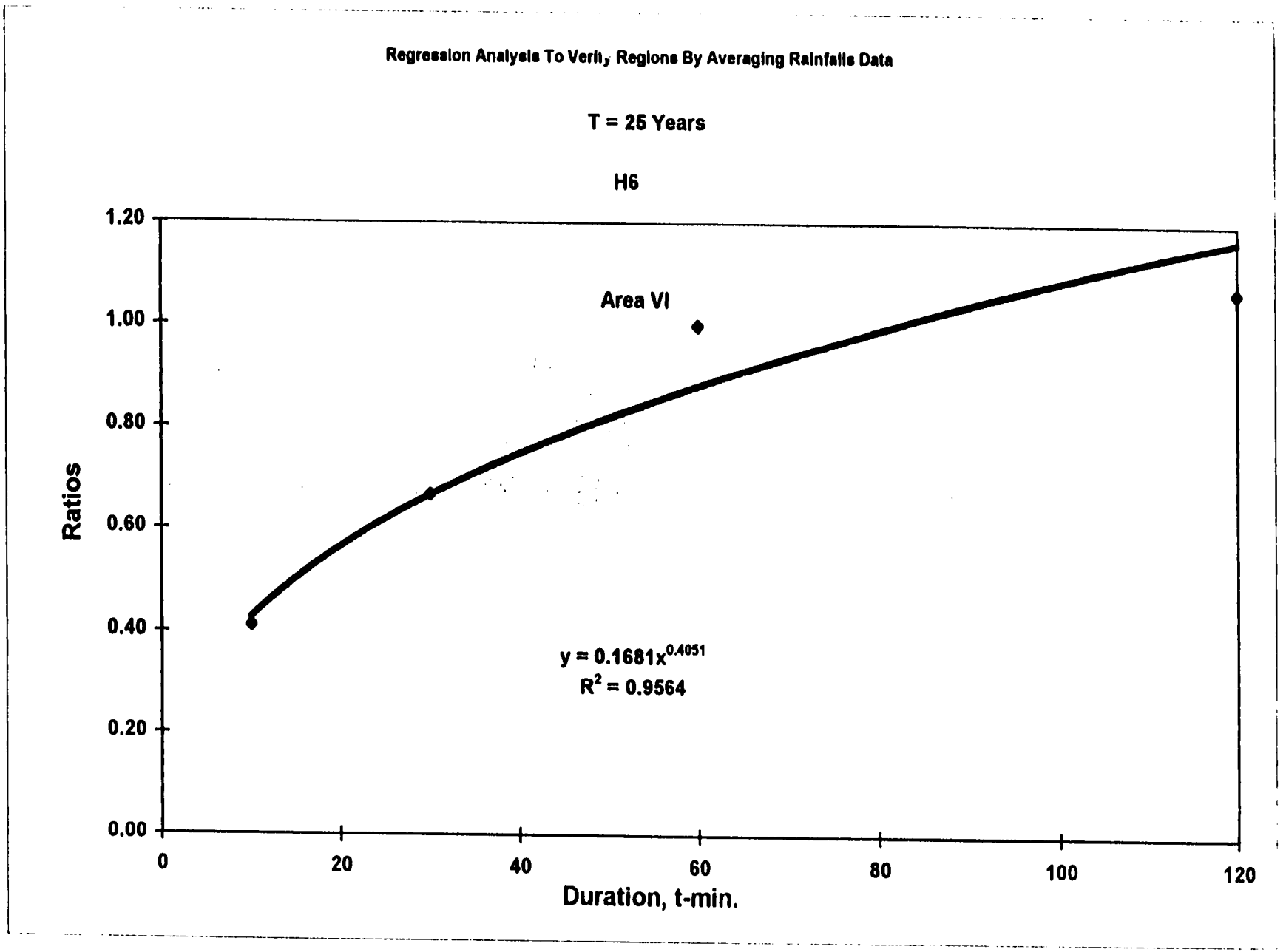


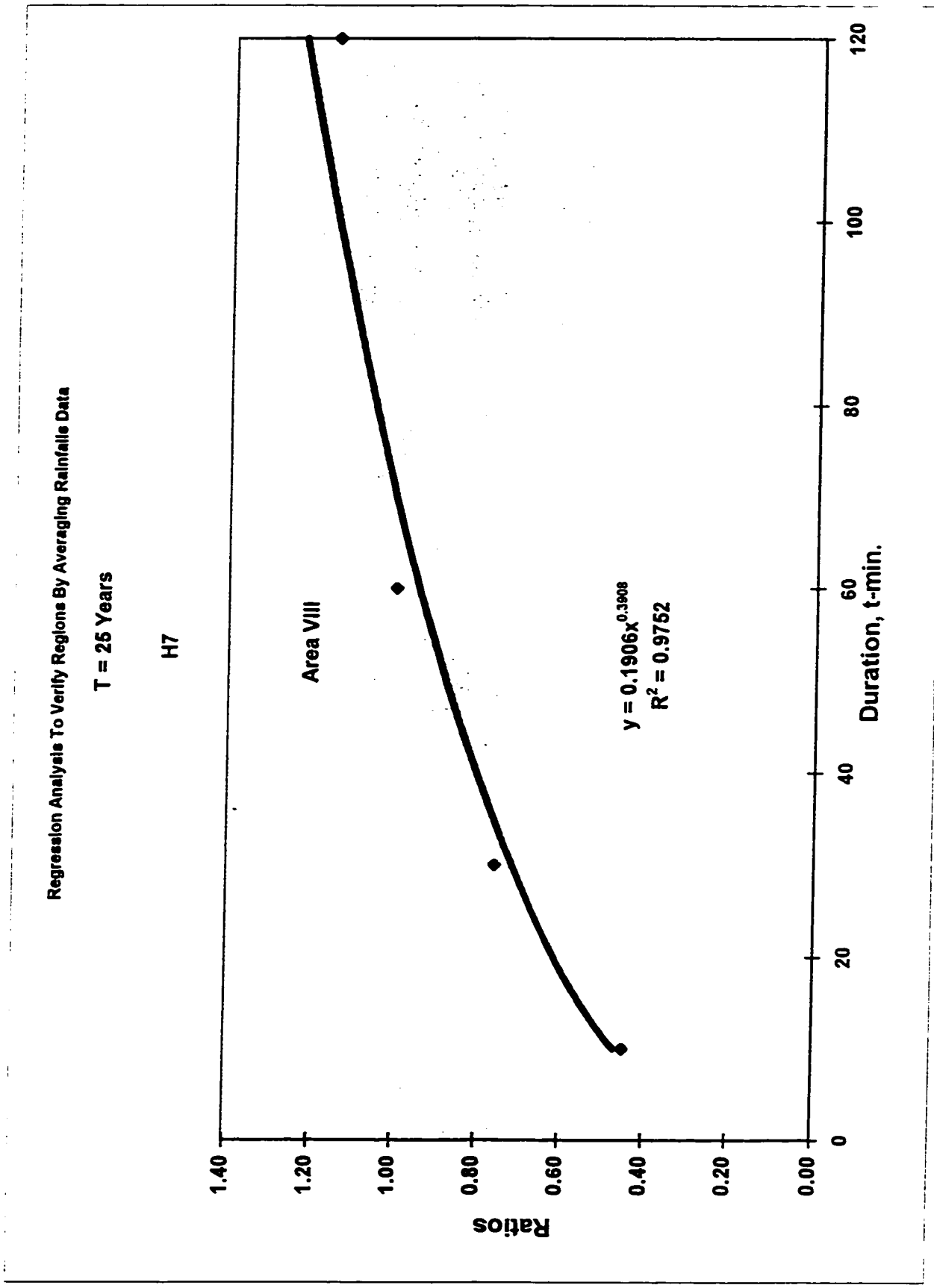

Regression Analysis To Verify Regions By Averaging Rainfalls Data
T = 25 Years
H2
Area II
y = 0.2875x^0.2852
R² = 0.856
Ratios
Duration, t-min.
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120

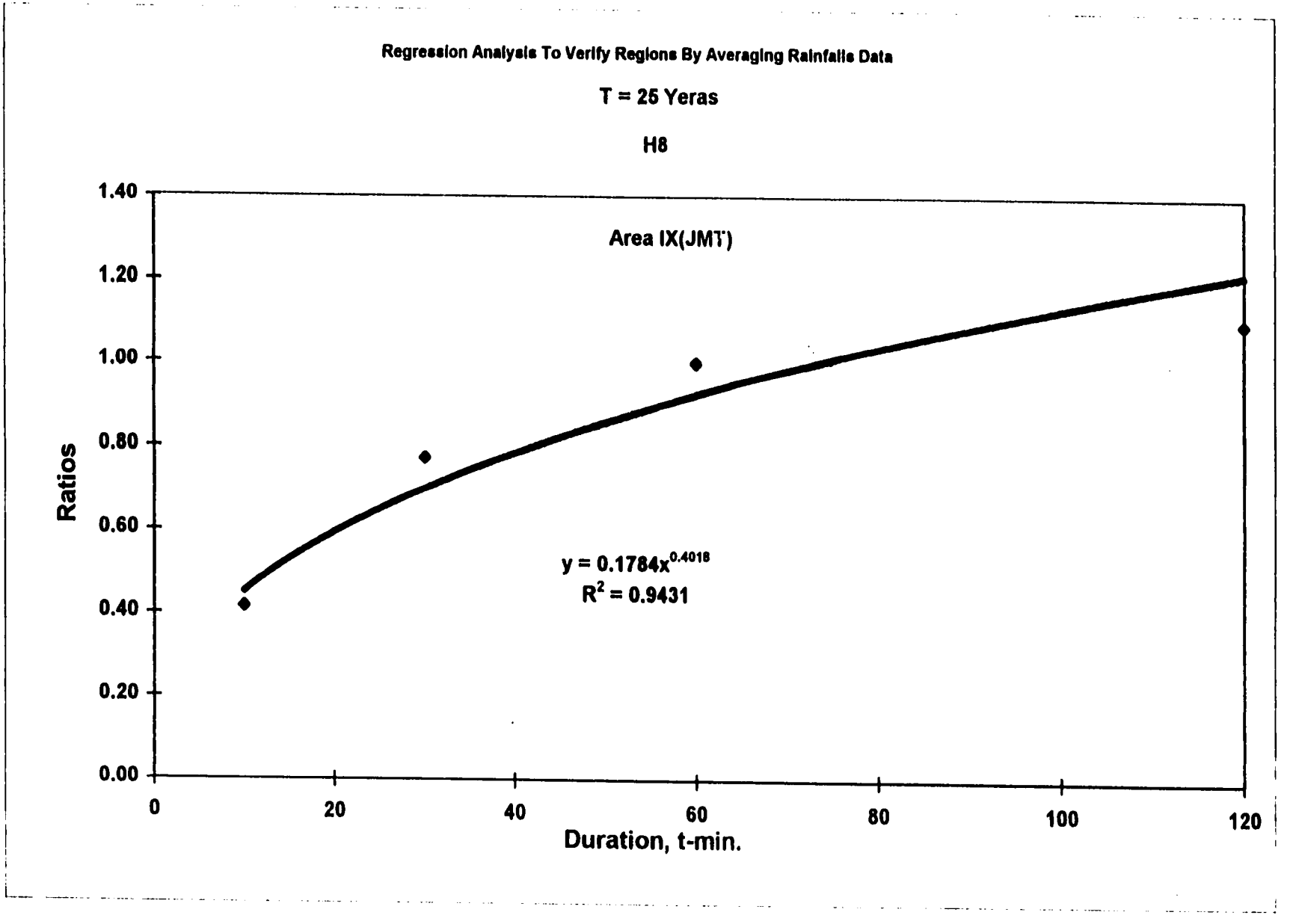

Regression Analysis To Verify Regions By Averaging Rainfalls Data
T = 25 Years
H3
Area III
y = 0.2712x^0.3065
R² = 0.942
Ratios
Duration, t-min.
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Regions By Averaging Rainfalls Data
T = 25 Years
H4
Area IV
y = 0.2329x^0.35
R^2 = 0.9929
Ratios
Duration, t-min.
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Regions By Averaging Rainfalls Data
T = 25 Years
H5
Area V
y = 0.1978x^0.4399
R² = 0.8945
Ratios
Duration, t-min.
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Regions By Averaging Rainfalls Data
T = 25 Years
H6
Area VI
y = 0.1681x^0.4051
R^2 = 0.9564
Ratios
Duration, t-min.
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Regions By Averaging Rainfalls Data
T = 25 Years
H7
Area VIII
y = 0.1906x^0.3908
R^2 = 0.9752
Ratios
Duration, t-min.
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120

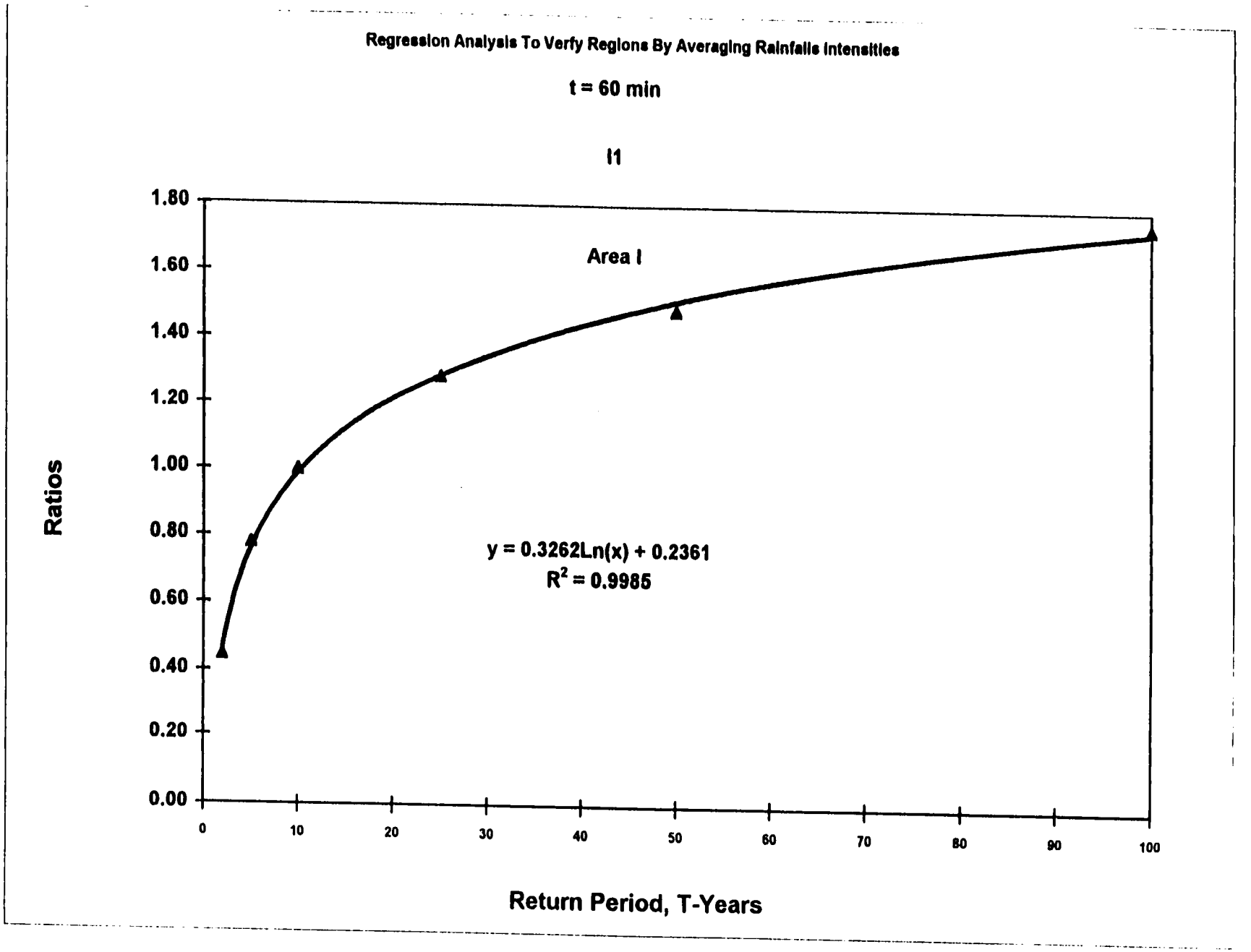

Regression Analysis To Verify Regions By Averaging Rainfalls Data
T = 25 Yeras
H8
Area IX(JMT)
Ratios
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
y = 0.1784x^0.4018
R^2 = 0.9431
0
20
40
60
80
100
120
Duration, t-min.

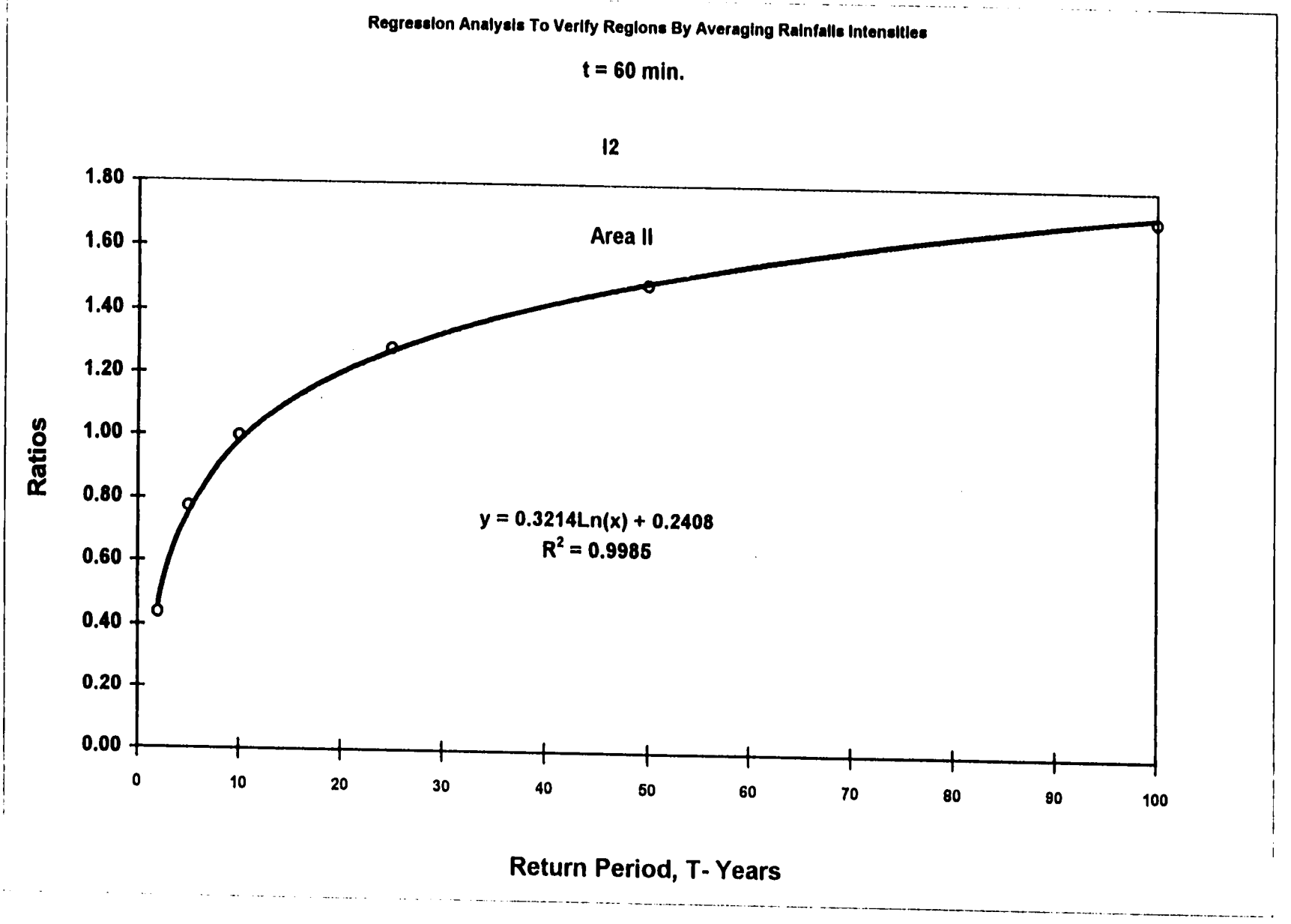
APPENDIX I

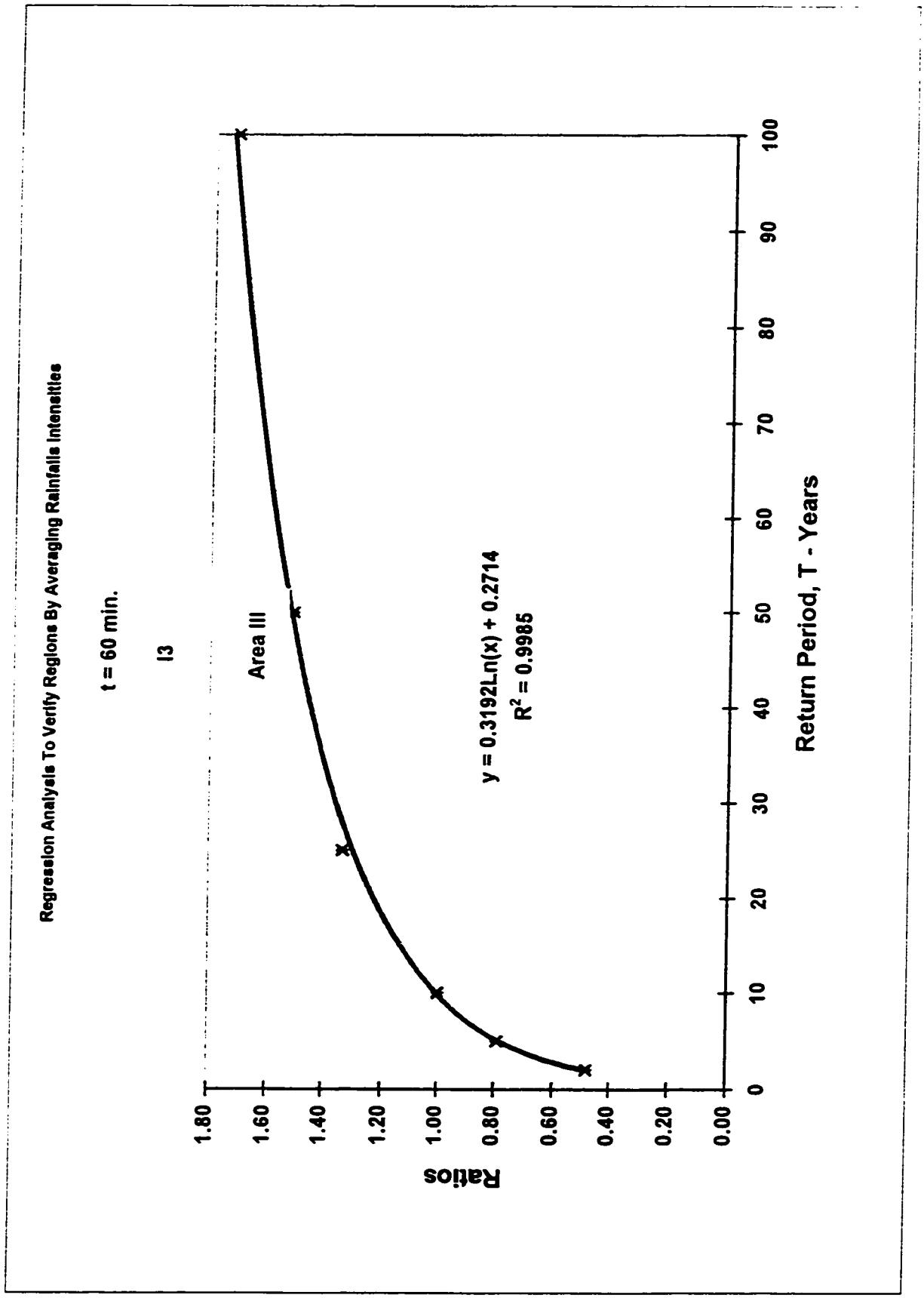
$I_1 - I_8$

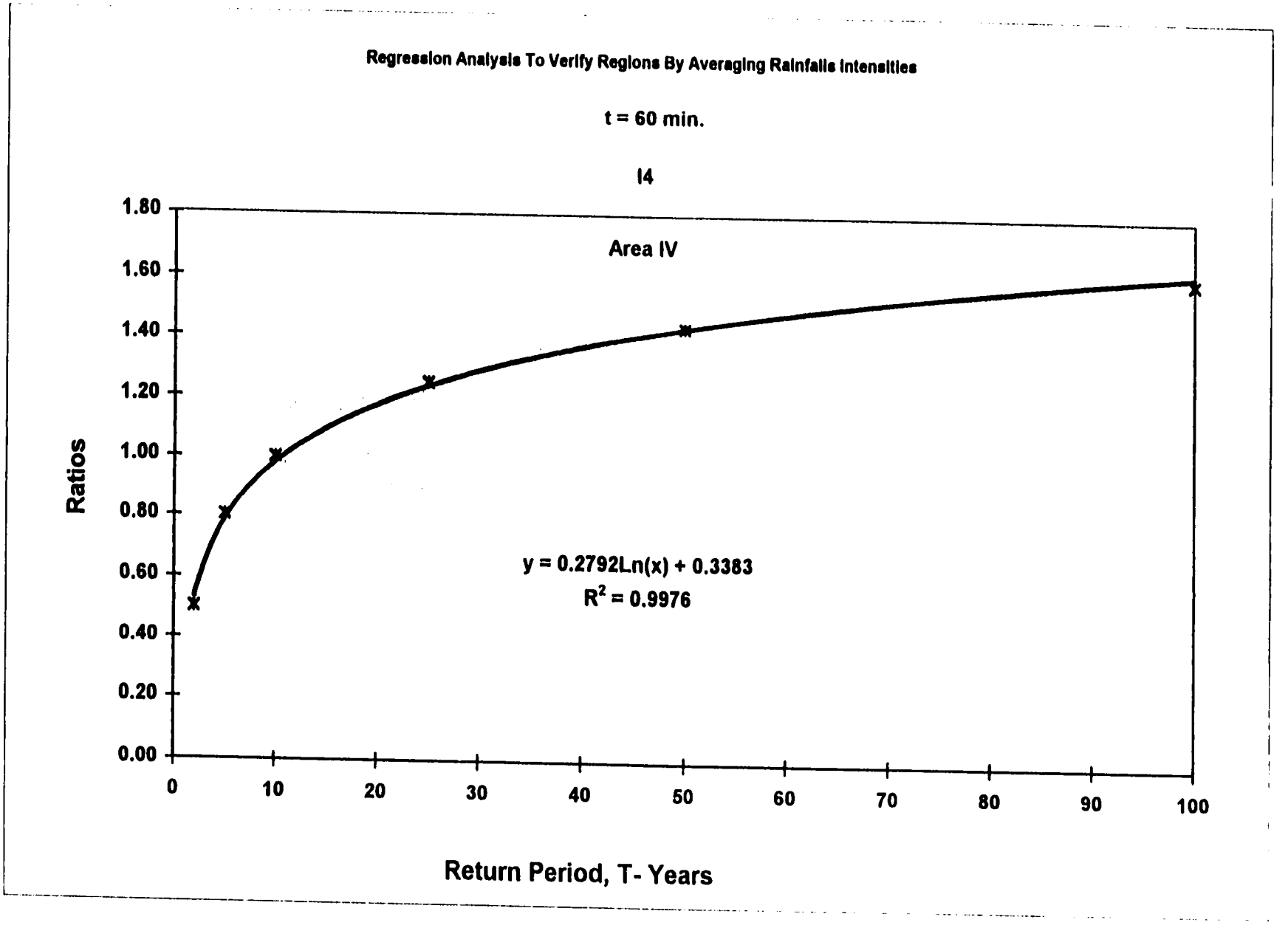
$$\frac{P_T^t}{P_{10}^T}$$

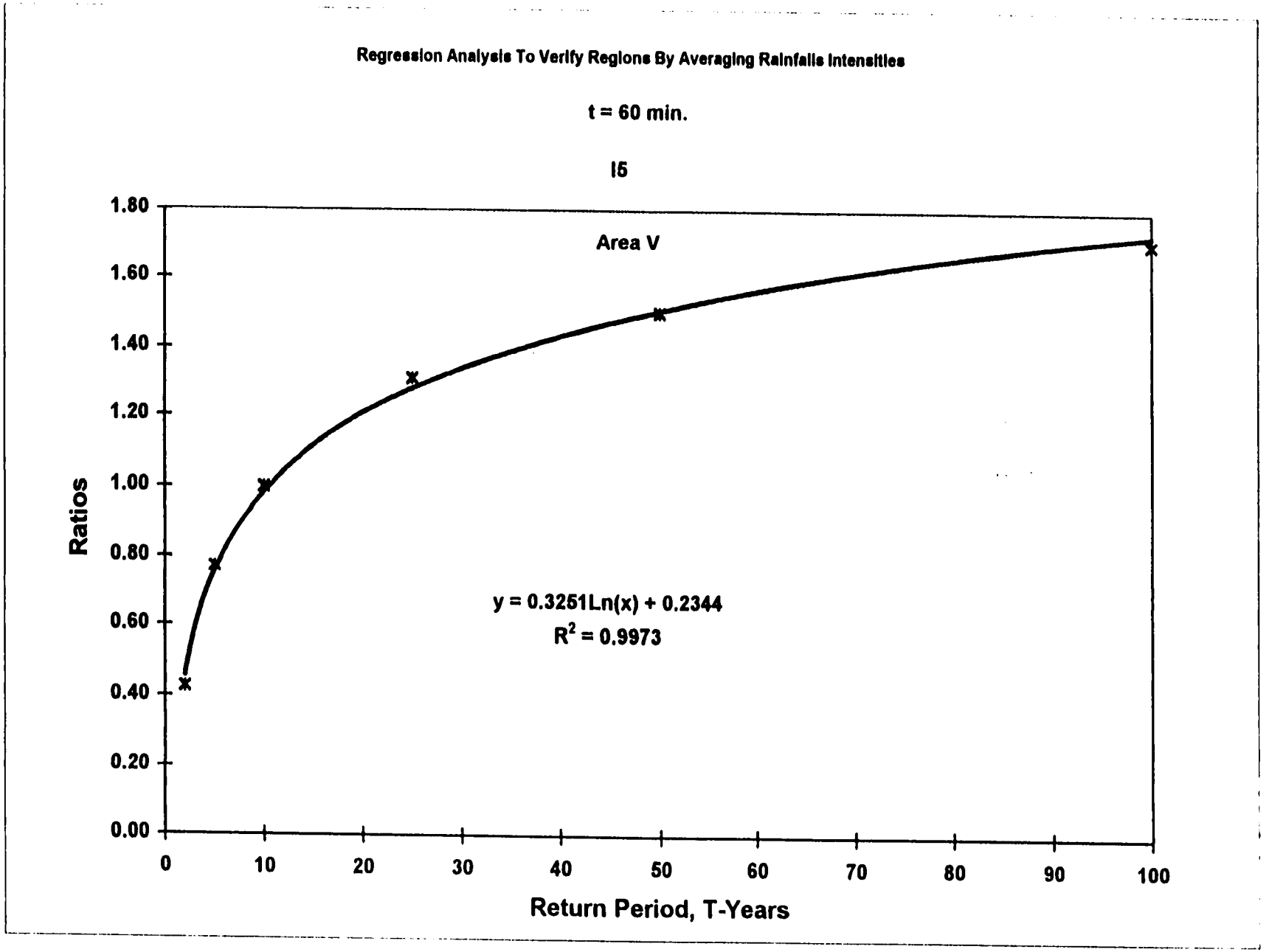
MODEL CURVES FOR AVERAGE INTENSITIES BY REGION

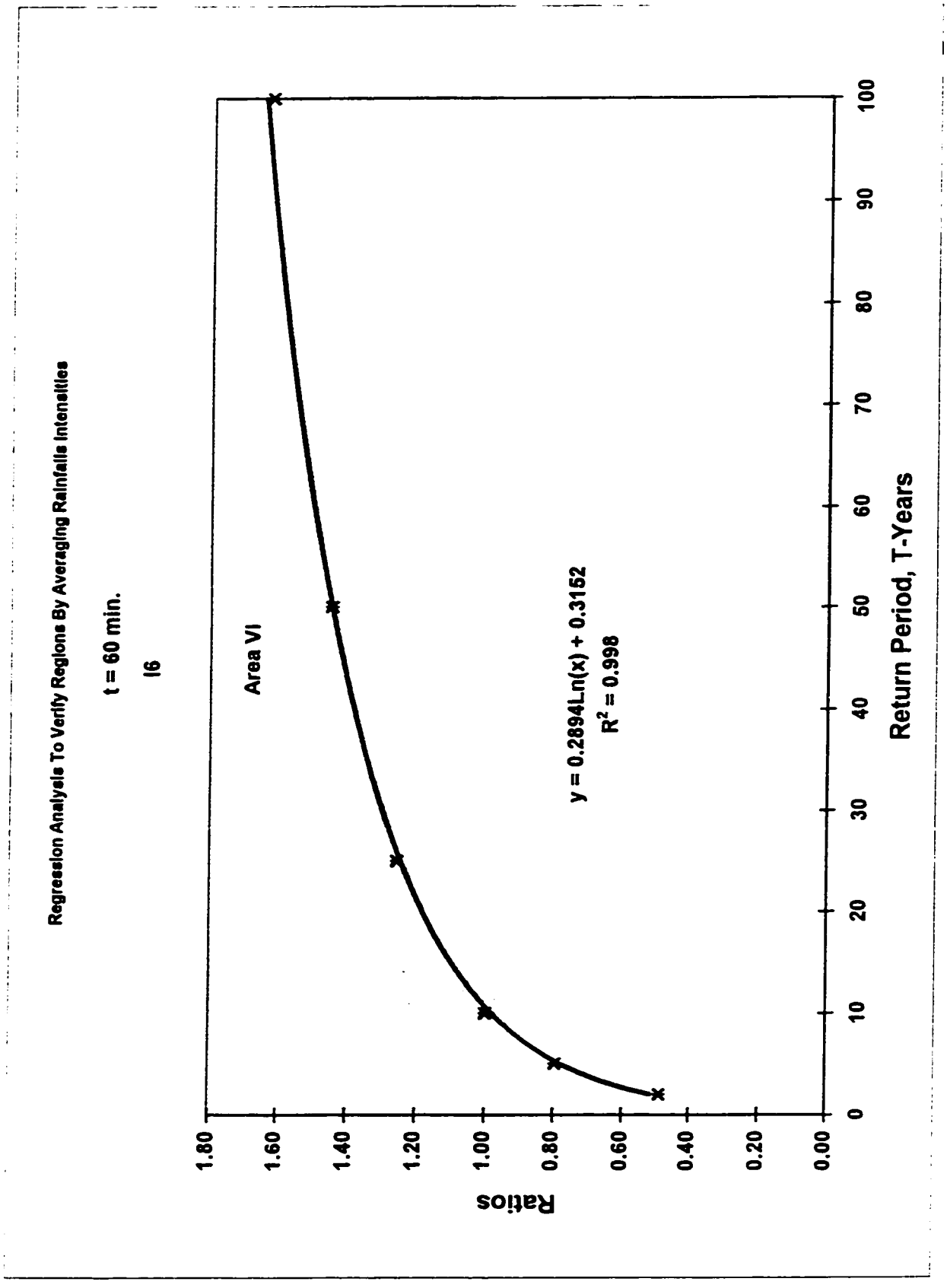

Regression Analysis To Verfy Regions By Averaging Rainfalls Intensities
t = 60 min
I1
Area I
y = 0.3262Ln(x) + 0.2361
R² = 0.9985
Ratios
Return Period, T-Years
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100


Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
t = 60 min.
I2
Area II
y = 0.3214Ln(x) + 0.2408
R2 = 0.9985
Ratios
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100
Return Period, T- Years


Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
t = 60 min.
I3
Area III
y = 0.3192Ln(x) + 0.2714
R2 = 0.9985
Ratios
Return Period, T - Years
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
0
10
20
30
40
50
60
70
80
90
100


Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
t = 60 min.
I4
Area IV
y = 0.2792Ln(x) + 0.3383
R2 = 0.9976
Ratios
Return Period, T- Years
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

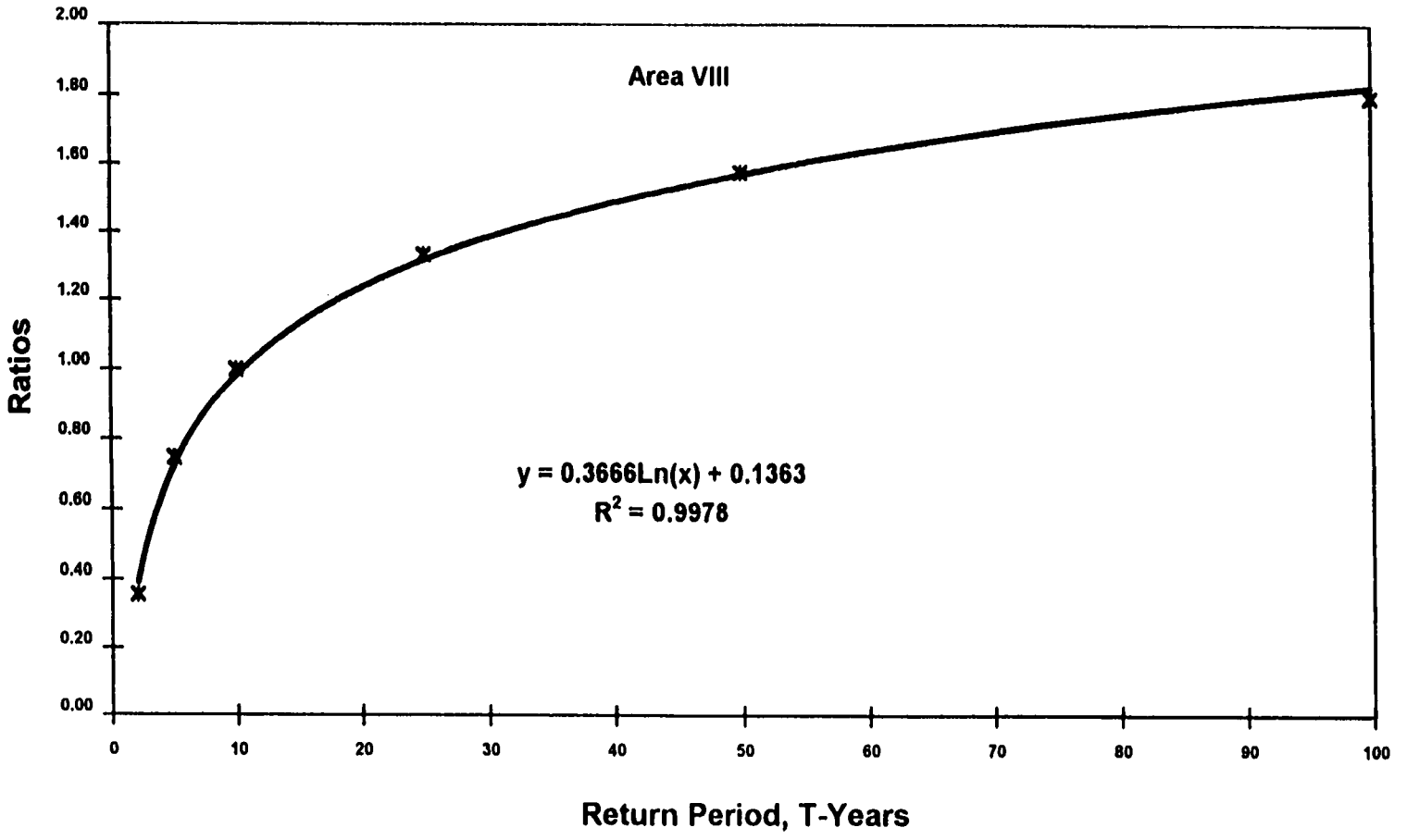

Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
t = 60 min.
I5
Area V
Ratios
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
y = 0.3251Ln(x) + 0.2344
R2 = 0.9973
0
10
20
30
40
50
60
70
80
90
100
Return Period, T-Years

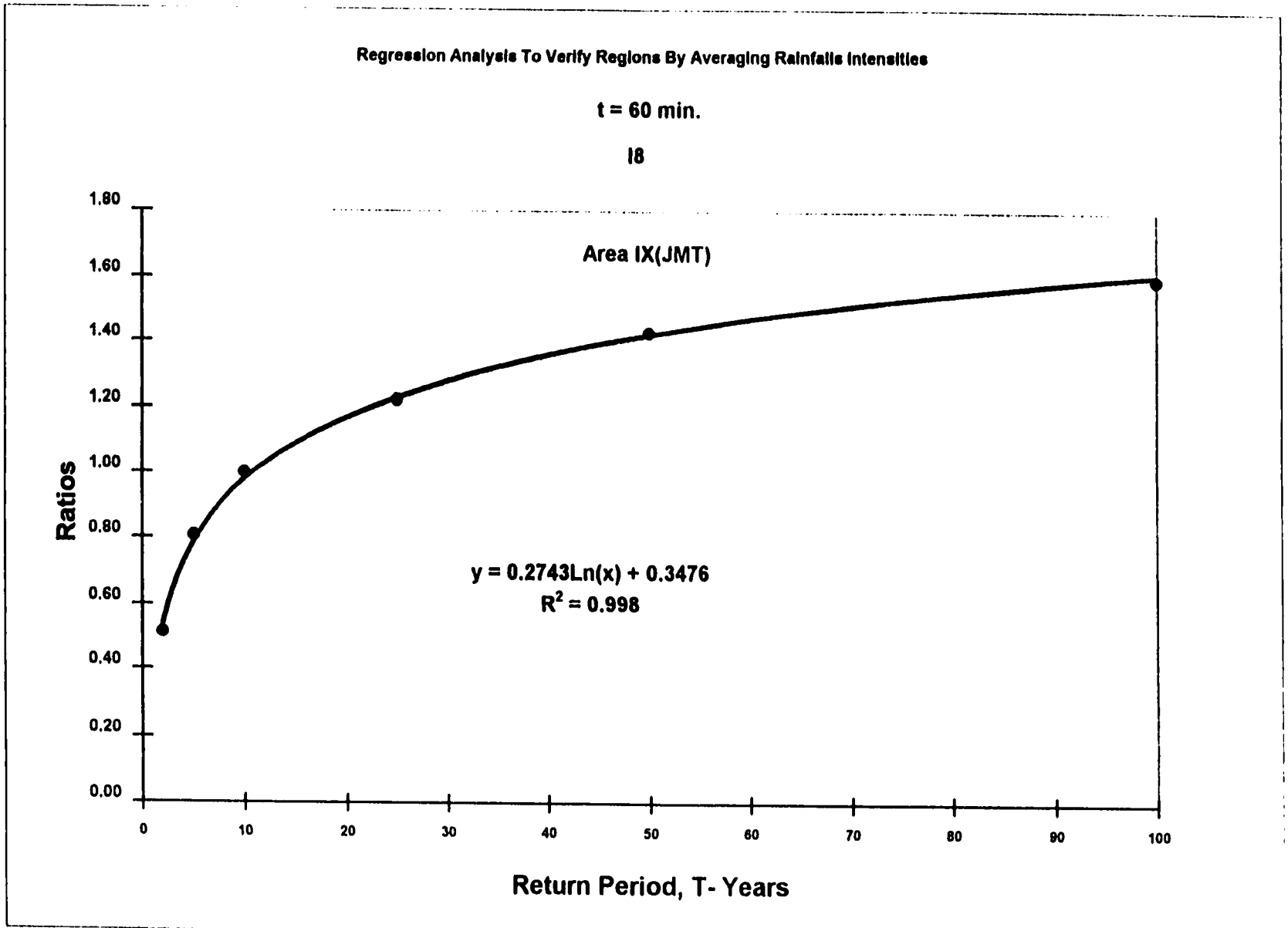

Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
t = 60 min.
I6
Area VI
y = 0.2894Ln(x) + 0.3152
R² = 0.998
Ratios
Return Period, T-Years
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100

Regression Analysis To Verify Regions By Averaging Rainfalls Intensities

t = 60 min.

I7



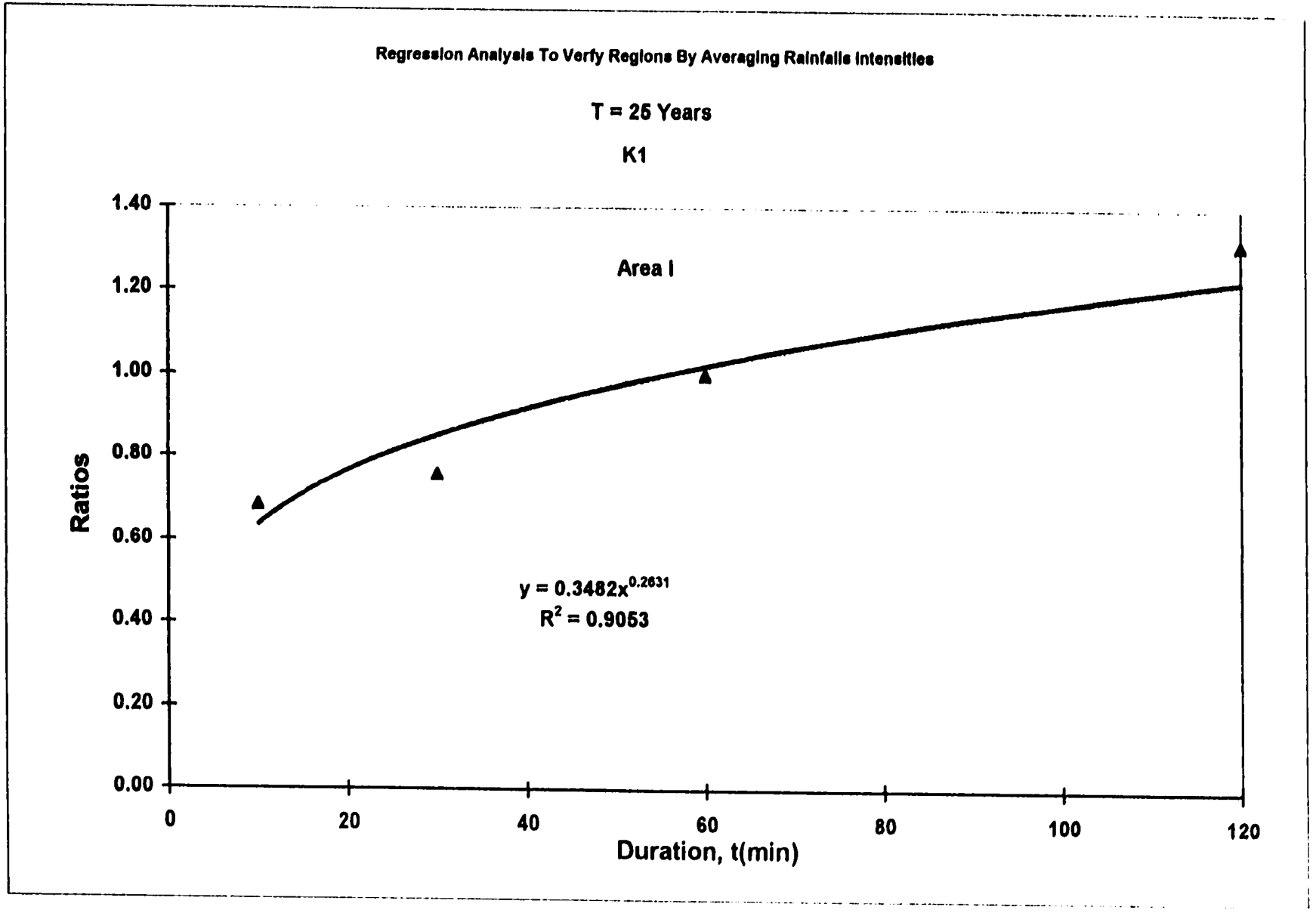

Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
t = 60 min.
I8
Area IX(JMT)
y = 0.2743Ln(x) + 0.3476
R2 = 0.998
Ratios
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100
Return Period, T- Years

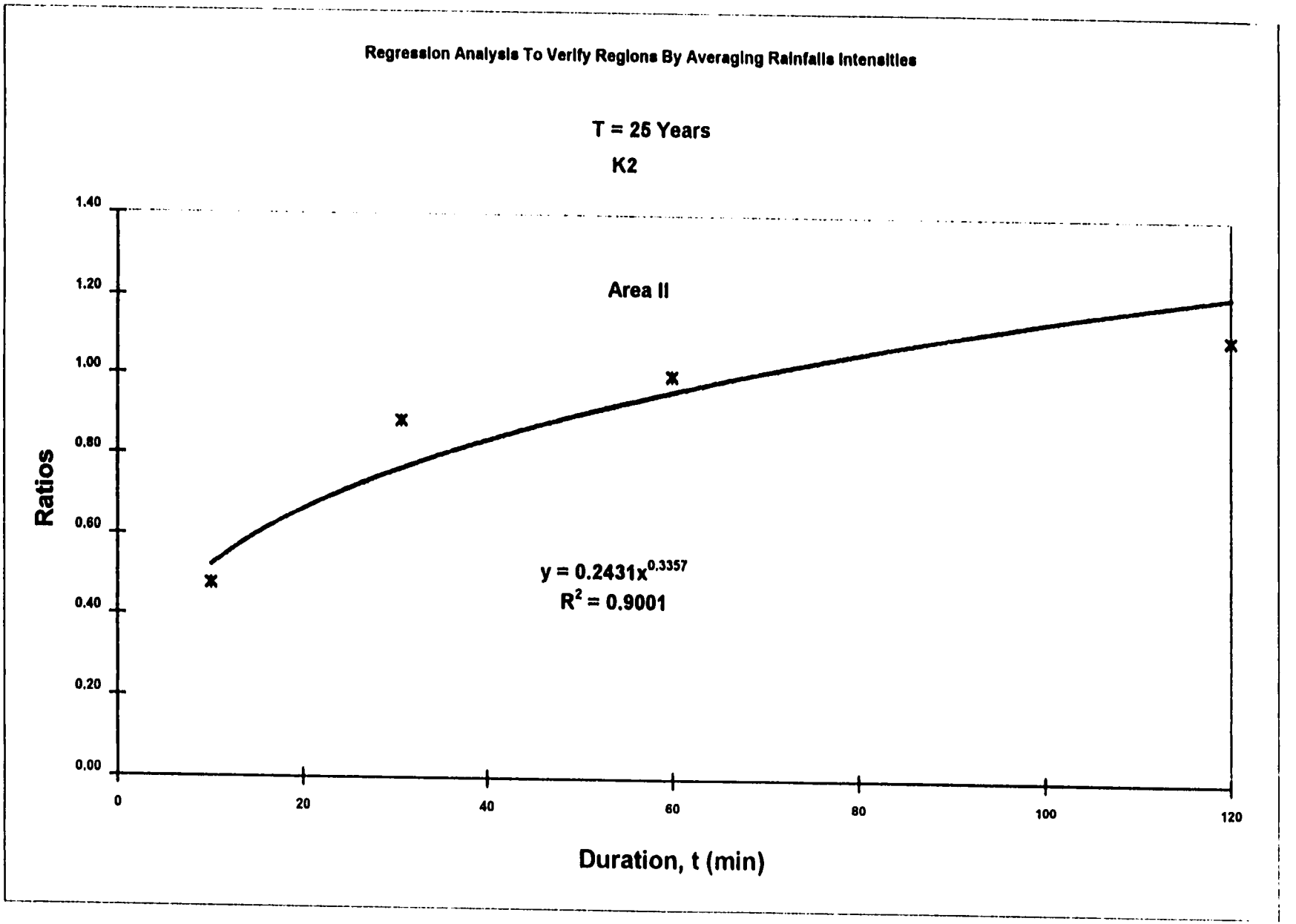
APPENDIX K

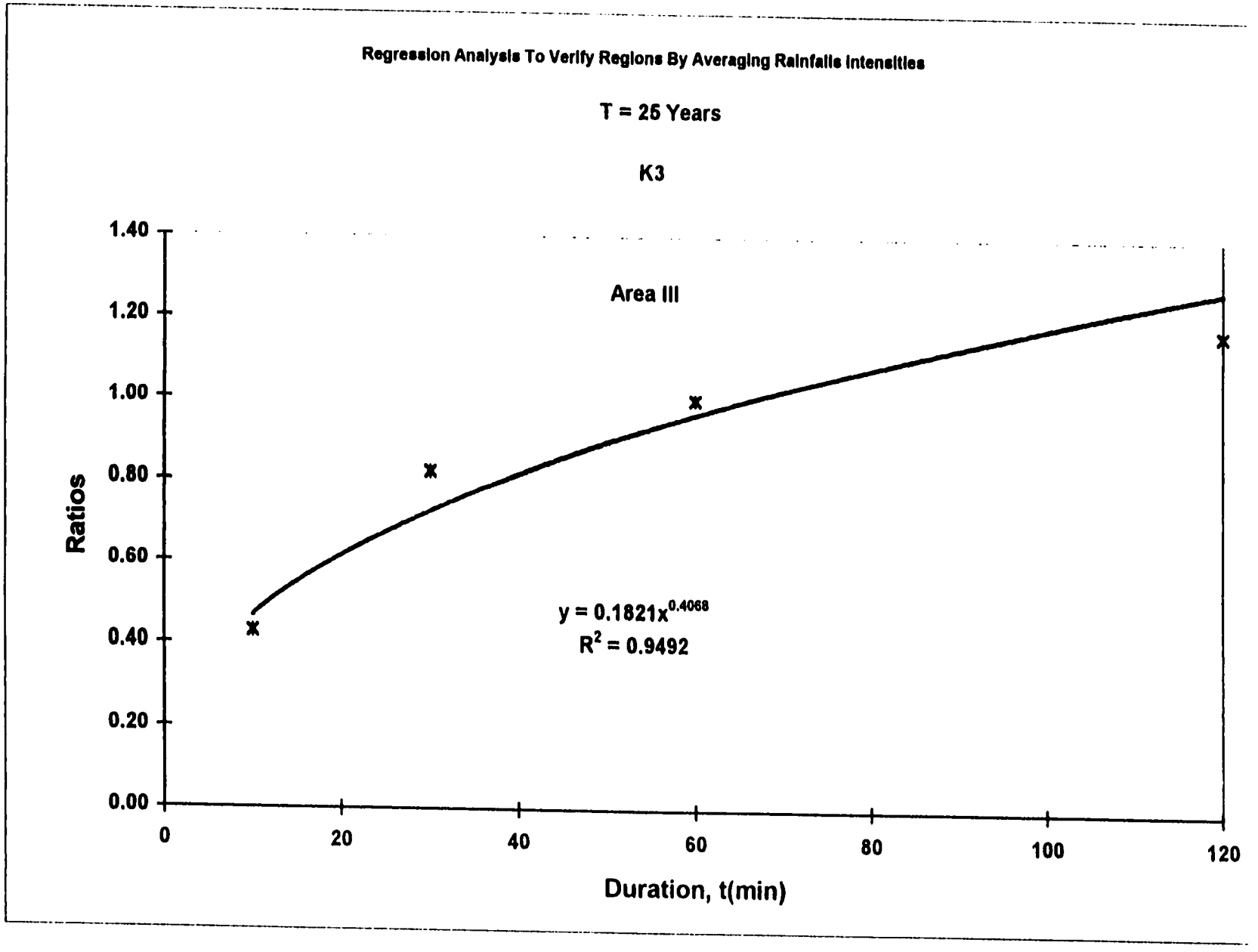
$K_1 - K_8$

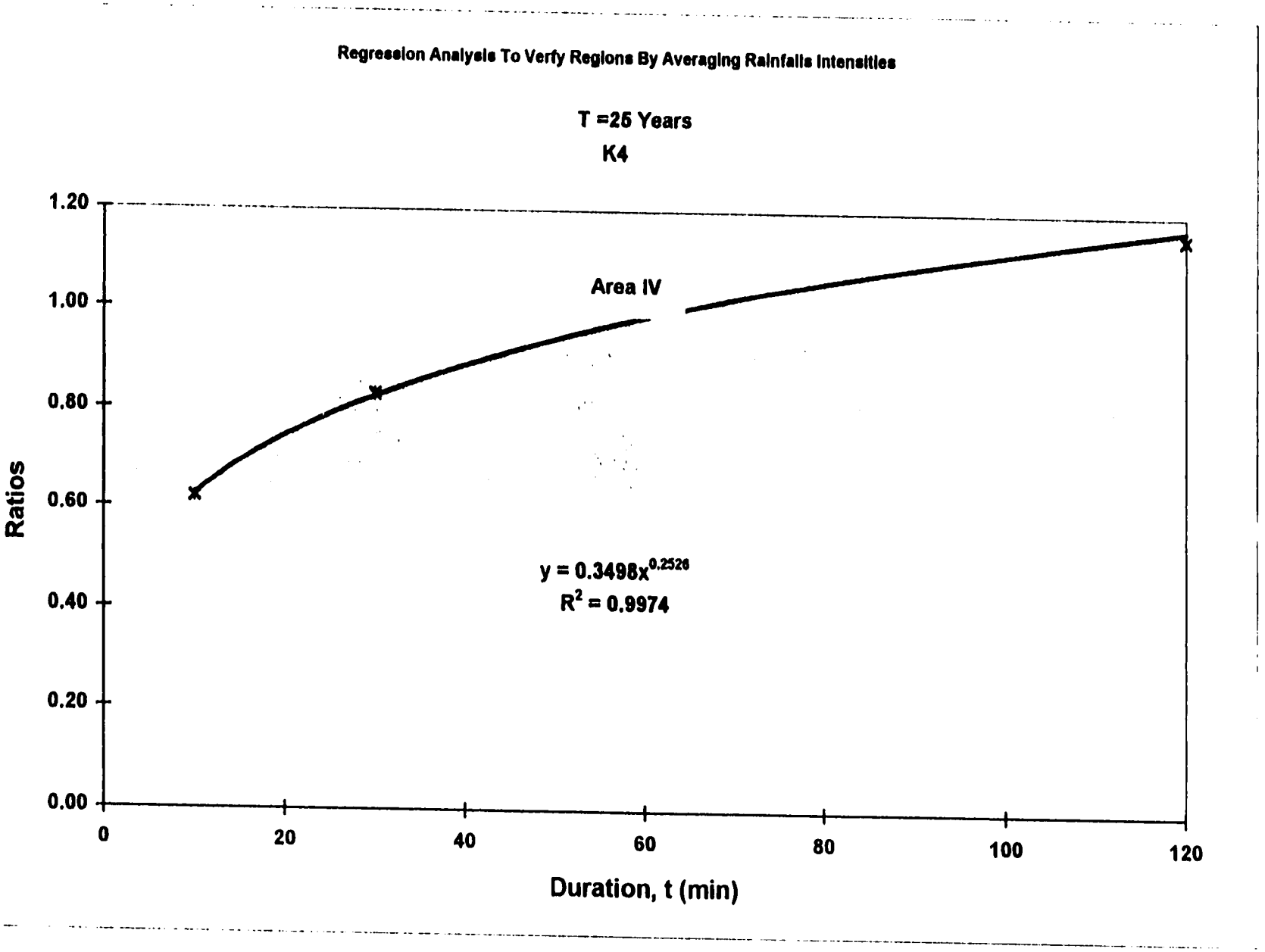
$$\frac{P_T^t}{P_T^{60}}$$

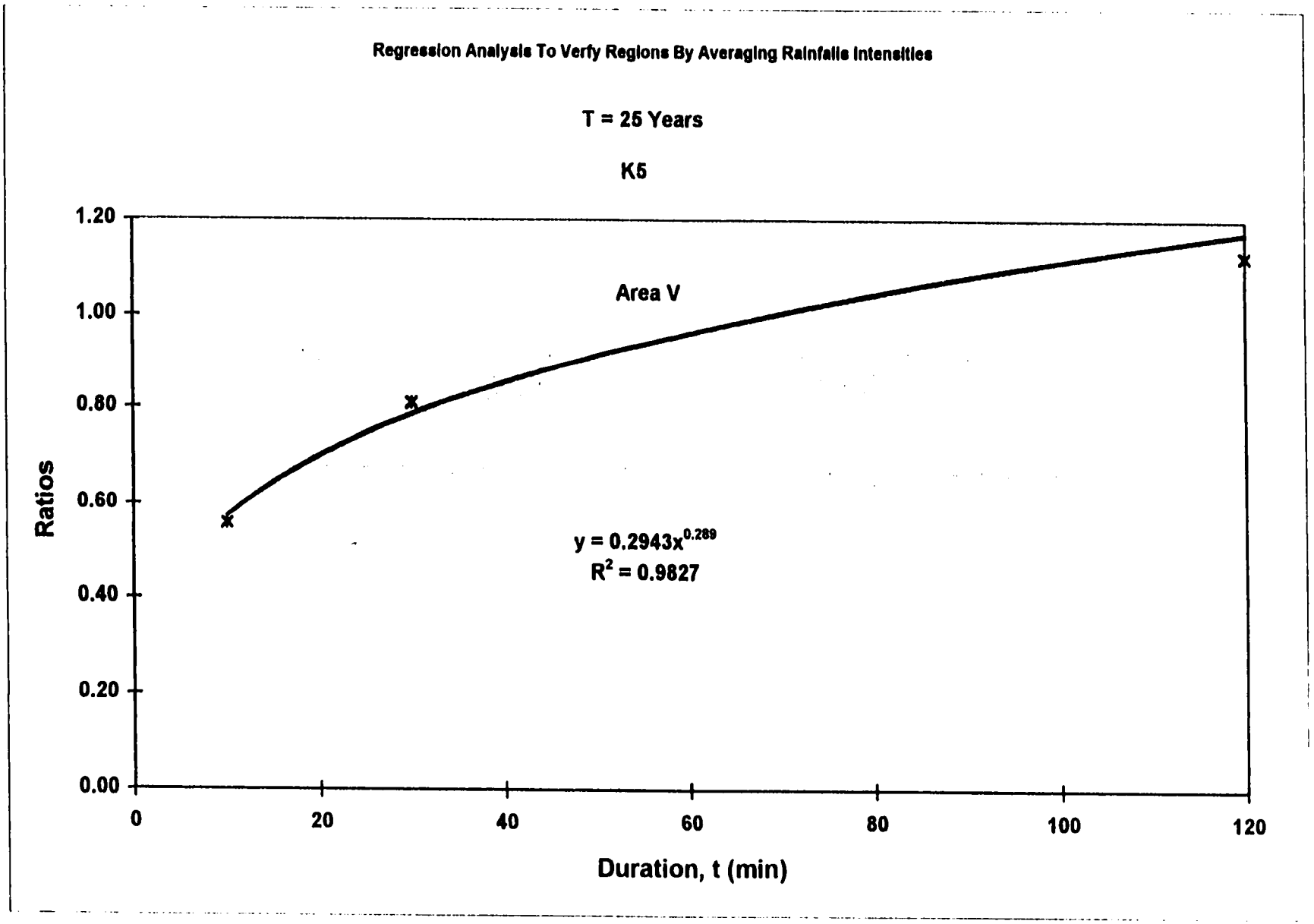
MODEL CURVES FOR AVERAGE INTENSITIES BY REGION

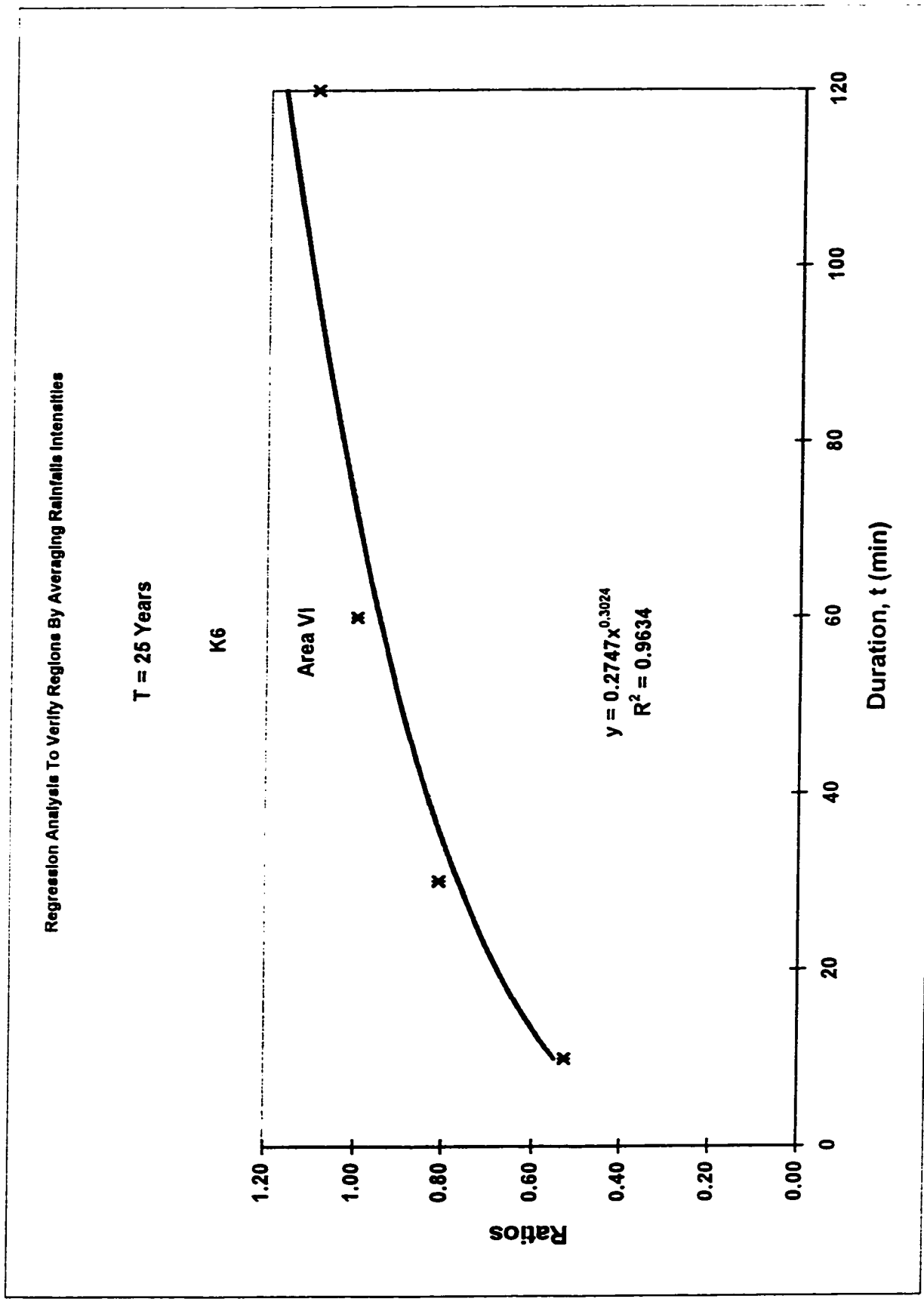

Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
T = 25 Years
K1
Area I
Ratios
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
y = 0.3482x^0.2631
R^2 = 0.9053
0
20
40
60
80
100
120
Duration, t(min)

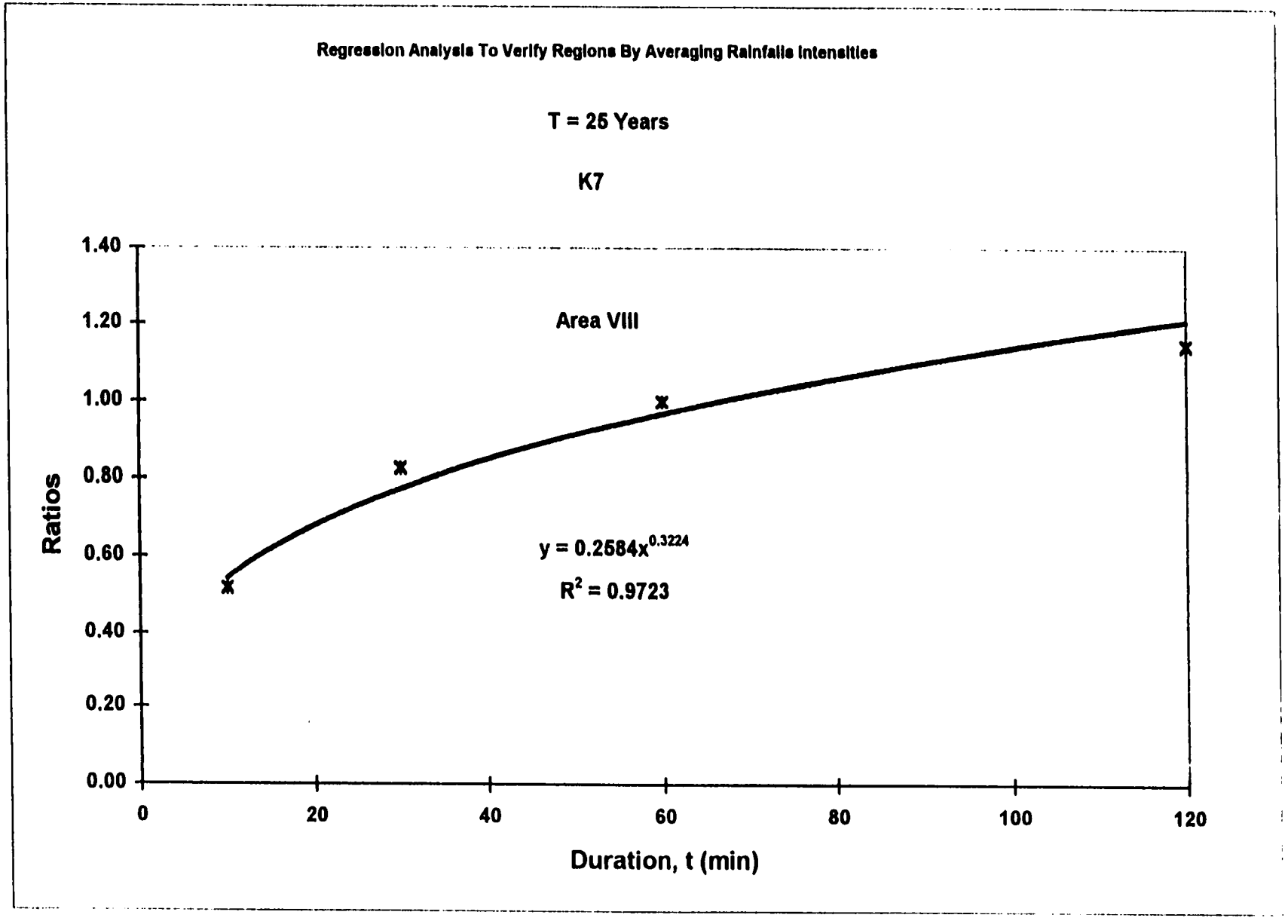

Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
T = 25 Years
K2
Area II
y = 0.2431x^0.3357
R^2 = 0.9001
Ratios
Duration, t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120

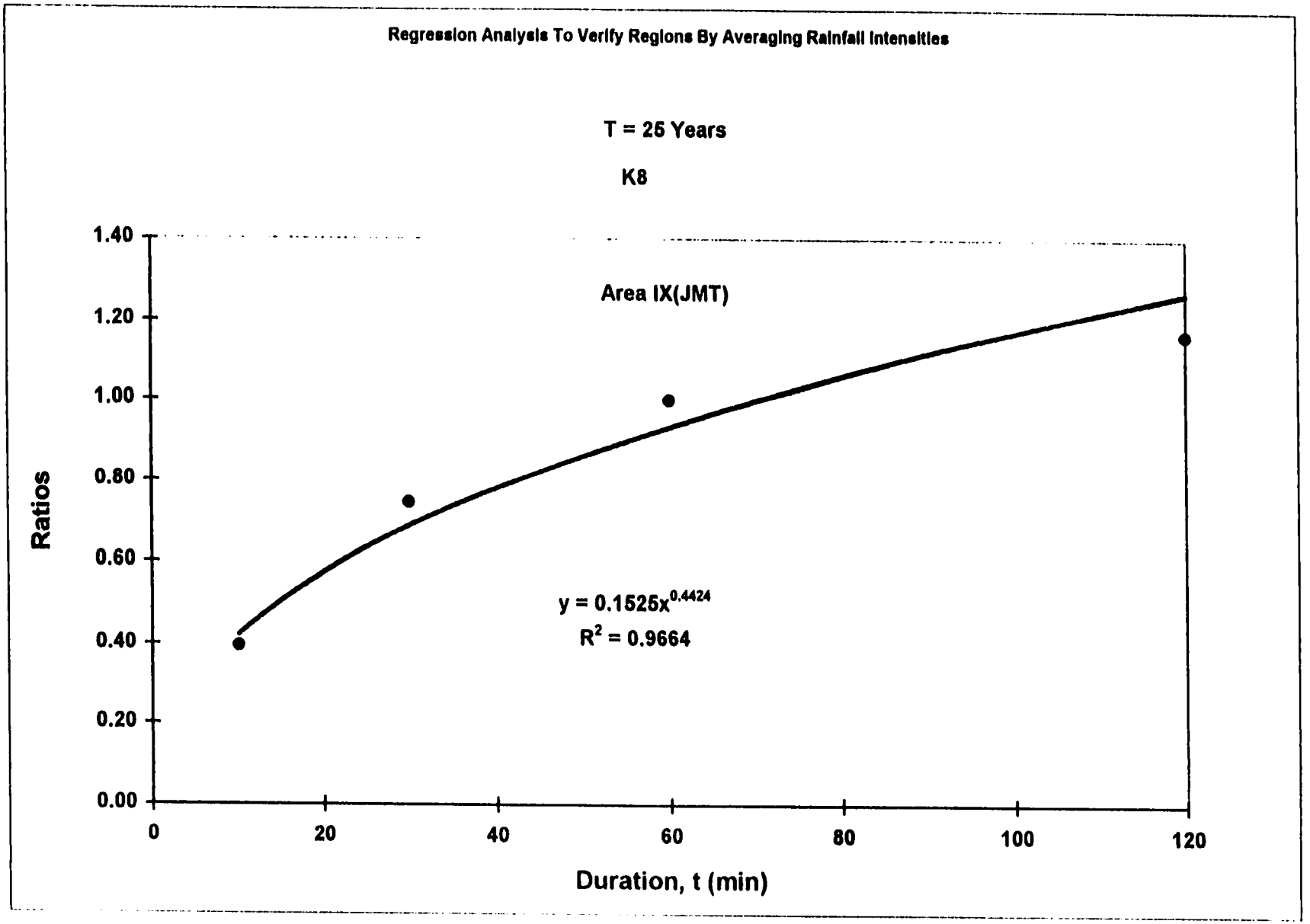

Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
T = 25 Years
K3
Area III
y = 0.1821x^0.4068
R^2 = 0.9492
Ratios
Duration, t(min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
T =25 Years
K4
Area IV
y = 0.3498x^0.2526
R² = 0.9974
Ratios
Duration, t (min)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verfy Regions By Averaging Rainfalls Intensities
T = 25 Years
K5
Area V
y = 0.2943x^0.289
R² = 0.9827
Ratios
Duration, t (min)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
T = 25 Years
K6
Area VI
y = 0.2747x^0.3024
R² = 0.9634
Ratios
Duration, t (min)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Regions By Averaging Rainfalls Intensities
T = 25 Years
K7
Area VIII
y = 0.2584x^0.3224
R^2 = 0.9723
Ratios
Duration, t (min)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120


Regression Analysis To Verify Regions By Averaging Rainfall Intensities
T = 25 Years
K8
Area IX(JMT)
y = 0.1525x^0.4424
R² = 0.9664
Ratios
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
20
40
60
80
100
120
Duration, t (min)

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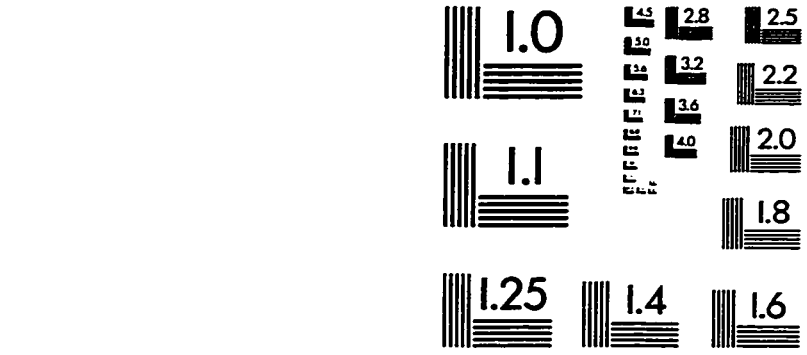
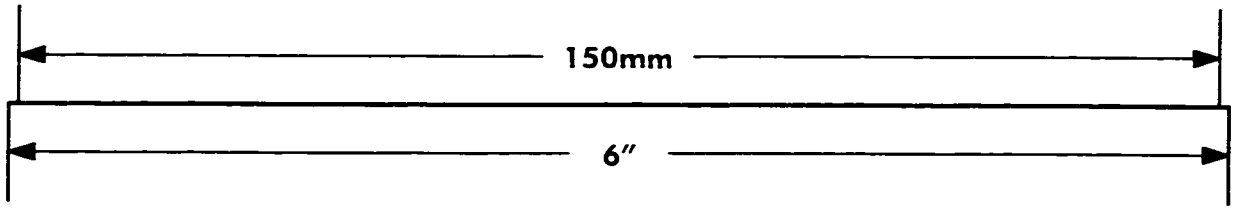
TEST TARGET (QA-3)





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