FALLOUT METHODS
Stokes Law Plot!

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T. N. White, H-6 [redacted] 11 March 1953

C. A. Spohn, H-6 Wea.

ANALYSIS OF THE ACCURACY OF FALL-OUT FORECASTS AND PLOTS USED
AT THE NEVADA PROVING GROUND
H-6

7/27/79

[redacted]

Ltr Redman 27 July 56

During the Buster-Jangle and Tumbler-Snapper test series, regular fall-out forecasts, based on the 24 hour wind forecast, were issued for each shot and presented at the briefings. In addition, fall-out plots were prepared from the Control Point wind soundings at approximately 2 hour intervals during the period from H minus 4 hours to H plus 4 hours. This study has been undertaken in an attempt to evaluate the accuracy of these fall-out forecasts and plots.

The first step was to prepare a post-analysis of the fall-out area, on the basis of the following assumptions:

a. Each particle falls at a constant (but not the same) rate of speed.

b. Fall-out takes place on a level plane (5000' msl was generally used)

c. The analysed wind fields are valid through a period extending from three hours before to three hours after synoptic time.

d. Each constant level analysis is valid through a layer extending 2500 feet above and below the analysis level (or 1000 feet each way if 2000 foot wind levels are analysed), with the gradient wind being valid from 7500 feet to the surface.

These assumptions were identical with those used in preparing the fall-out forecasts (or plots), with the exception of "c" and "d", in which analysed wind fields were substituted for point wind forecasts (or soundings). The post analysis would thus show most of the error due to the inaccuracies of the wind forecast (this forecast error is almost certainly the major error), but not the error due to the assumptions of a constant fall rate, a level surface, and quasi-constancy of the wind field.

Once the wind field analysis was completed, the paths of particles starting from various heights, and with fall times of 3, 6, and 9 hours were computed. The terminal positions of these trajectories were than compared to the terminal positions for the same points of origon and fall times as given by the fall-out forecasts (or plots).

The results of this comparison are presented here in the form of two error analyses. The first of these errors is the bearing error, defined as the angular measure of the amount by which the line from

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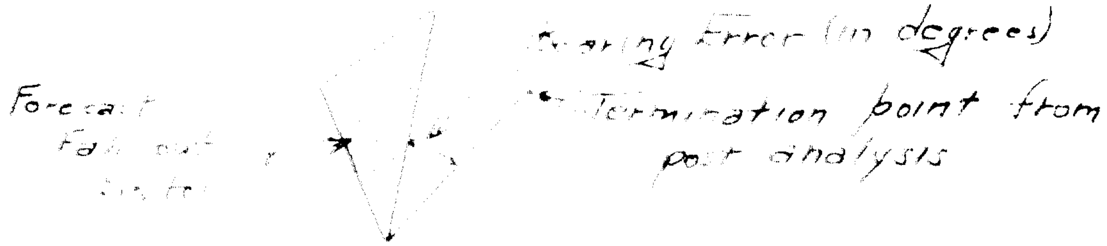
zero to the analysed termination point fall outside the fall-out sector as established by the forecast for plot.



The second error is the absolute error, defined as the distance in statute miles between the termination points established from post analysis and from the forecast.

Early in the analysis it became apparent that the 3, 6 and 9 hour absolute errors were directly proportional to the time, while the bearing errors were generally independent of time. For this reason, the error values given in the tables that follow were handled as indicated:

a. Bearing errors - Values for 3, 6, and 9 hours considered in a common group with no distinction due to time.

b. Absolute errors - 6 hour values were divided by 2, 9 hour values were divided by 3, these adjusted values being grouped with the 3 hour values.

The data were broken down into high level (above 20,000') and low level (20,000' and down) fall-out. This had the advantage of separating the fall-out from the cloud proper (high level fall-out) and the fall-out from the stem (low level fall-out), except in those cases in which the cloud did not reach 20,000'. There were four such cases in the fourteen studied, giving a total of 28 low level and 20 high level trajectories computed for each time interval, since two initial altitudes were used in each high level and low level region. Since the sample size was not very large (82 low level, 56 high level obtained by lumping 3, 6 and 9 hour figures; there were no 9 hour values for Tumbler-Snapper V and no 9 hour high level values for Buster Dog because of high wind speeds), the statistics presented are the median and the third quartile values (i.e. values which are greater than 50% and 75% of the values respectively.) Table I, following, gives these values for all the cases grouped together.

Table I

Median and Third Quartile Error Values for All Cases

		Low Level		High Level	
		Forecast	Plot	Forecast	Plot
Bearing Error	Median	13°	5°	12°	5°
	3rd Qua.	46°	18°	35°	14°

		Low Level Forecast	Low Level Plot	High Level Forecast	High Level Plot
Absolute Error (statute miles)	Median	34	23	31	21
	3rd Qut.	47	33	57	30
Mean Distances		46	51	76	85

The mean distances listed at the bottom of the table are the mean 3 hour travel distances computed from the fall-out forecasts or plots, and are included as a basis for judging the magnitude of the absolute errors. It can be seen from the table that the high level fall-out is more accurately forecast than the low level fall-out. This difference is best indicated for the bearing errors by the 3rd quartile values, which show the lesser number of large errors in high level fall-out. For the ~~bearing~~ absolute errors, comparison with the mean 3 hour distances shows that at high levels even the 3rd quartile values are appreciably less than mean distances, whereas the low level values approximate the mean distance figures. Even more striking than the high and low level differences is the much greater accuracy of the fall-out plots as compared to the fall-out forecasts. The median bearing error values for the fall-out plots are especially striking in view of the fact that the mean fall-out sector spread for the plots is 26°, while the mean spread from analysis is 37°. Thus, even if the axes of the sectors coincided, the greater width of the analysed sectors would result in a mean bearing error of approximately 2.5°. (For the forecasts the mean sector spread is 20°, leading to a mean bearing error of 4.5°). Thus it can be seen that the fall-out plots are generally quite accurate, especially with respect to the bearing errors.

Graphically, the bearing error may be pictured as a pair of sectors lying to either side of the forecast fall-out sector, while the absolute error can be pictured as a circle about the termination point of the resultant vector. Figures 1 thru 4 attached show the errors from Table I so laid out.

After the general analysis had been completed, it was decided to break down the data on two criteria. First, the data were separated on the basis of the type of shot (i.e., tower or air) and secondly, the magnitude of the wind speed was used as the criterion of division. The choice of these particular criteria was on a dual basis. First, these represented definite hazard differences, on the one hand because of the much greater fall-out with tower shots and on the other hand because of the probability of having the maximum fall-out levels outside the range area in high wind situations. Second, there was reason, meteorologically, to believe that there would be a definite difference. Much more stringent wind requirements were used for tower shots, which implicitly included a confidence factor, since a tower shot would not be scheduled unless the forecast was considered to have a high probability of verifying. Similarly, weather situations which produce high wind speeds generally permit more accurate wind direction forecasts than do those producing light wind speeds. The criteria used to choose between strong and light winds was the length of the forecast three hour resultant vector. If this vector was greater than 40 miles for low level fall-out or 7[illegible] miles for high level fall-out, the wind speeds were considered strong.

Tables II and III following give the error distribution according to these breakdowns. The mean [illegible] hour vector distances have been included in the absolute error tabulation as a basis for comparison.

Table II

Fall-out Forecast Errors for Tower Shots versus Air Drops

		Low Level		High Level	
Bearing Error		Tower	Air	Tower	Air
	Median	8°	34°	12°	12°
Forecast	3rd Qut.	22°	58°	66°	33°
	Median	4°	6°	12°	3°
Plot	3rd Qut.	14°	21°	27°	9°
Absolute Error					
	Median	20	41	41	43
Forecast	3rd Qut.	34	52	55	65
	Mean Distance	(38)	(52)	(64)	(84)
	Median	20	25	27	22
Plot	3rd Qut.	26	35	36	26
	Mean Distance	(59)	(45)	(102)	(73)

Table III

Fall-out Forecast Errors for Strong Wind versus Light Wind Shots

		Low Level		High Level	
Bearing Error		High Wind	Light Wind	High Wind	Light Wind
	Median	12°	35°	10°	1°
Forecast	3rd Qut.	19°	62°	33°	52°
Plot	Median	2°	18°	2°	16°
	3rd Qut.	4°	43°	4°	18°
Absolute Error					
	Median	17	29	51	23
Forecast	3rd Qut.	30	44	58	40
	Mean Distance	(34)	(26)	(92)	(53)
Plot	Median	28	20	26	19
	3rd Qut.	[illegible]	25	36	23
	Mean Distance	([illegible])	(24)	(110)	(47)

Low level bearing errors for tower shots are markedly less than for air drops, especially in the forecasts. The high level breakdown shows no such distinction, with the air drop actually being more accurate in the plots. Similarly, the tower shots have smaller absolute errors at low level, but the high level absolute errors are approximately the same for both types of shots. This lack of distinction is even more pronounced if the absolute errors are compared to the mean three hour distance for each group.

Considering the wind speed breakdown, it is apparent that the bearing errors are much less in the case of strong winds. At first glance, the absolute errors appear to favor the light wind situation. This is a natural result of the division, for by selecting only those cases which have rapid movement, we are insuring that the magnitude of the absolute errors are a maximum. In comparison to the mean three hour distances (i.e., percentagewise), however, it is apparent that the absolute errors in the strong wind cases show a more favorable situation than do the absolute errors for the light wind case. Figure 5 illustrates this graphically, by showing the respective median absolute errors plotted on the fall-out diagrams formed by the mean 3 hour vectors.

The two analyses just shown indicate that in the most critical cases, i.e., those in which a maximum of debris is present and those in which high winds might carry the debris beyond the range area before the major fall-out occurs, the greatest accuracy is attained.

As a final check, the forecasts, plots, and post-analyses of fall-out were compared to the data obtained by the Rad-Safe off-site monitoring section in their fall-out trays. Because of the nature of the Rad-Safe operations, this data could not be used very rigorously. Since the purpose of the Rad-Safe unit was to protect the civilian population surrounding the Proving Ground, the trays were almost invariably located in population centers, rather than distributed uniformly about the area. Consequently, in some instances there might be no tray located in the path of the fall-out.

The method finally employed was to select, by visual inspection of the data, a threshhold value for each shot (data were available for six shots of the spring series). A tabulation was then made of the percentage of all stations within the area as forecast (plotted or analysed) which had fall-out values exceeding the threshhold value. A similar tabulation was then made of the stations outside the area which had values below the threshhold value. These tabulations were expressed in percentages of all stations within or outside the area, respectively, and the percentages then averaged for each shot, and finally averaged for all six shots.

T. N. White

11 March 1953

The results are as shown:

	Forecasts	Plots	Post Analysis
Inside Stations above Threshhold	57%	80%	86%
Outside Stations below Threshhold	92%	88%	95%
Total	79%	84%	91%

In conclusion, while it is evident that the present technique has some deficiencies, especially in light wind forecast situations, it seems likely that the operational need for a simple technique will preclude any drastic changes. A realistic acceptance of the accuracy of the method, combined with a program of regular checks on the forecast thru the use of fall-out plots should continue to give a service which is satisfactory for needs at the Nevada Proving Ground.

Clifford A. Spohn
Lt Col, USAF
Detachment Commander

cc: J. C. Clark, J-10
Col. [illegible] Taylor
Lt. Col. Wm. Wyatt
File

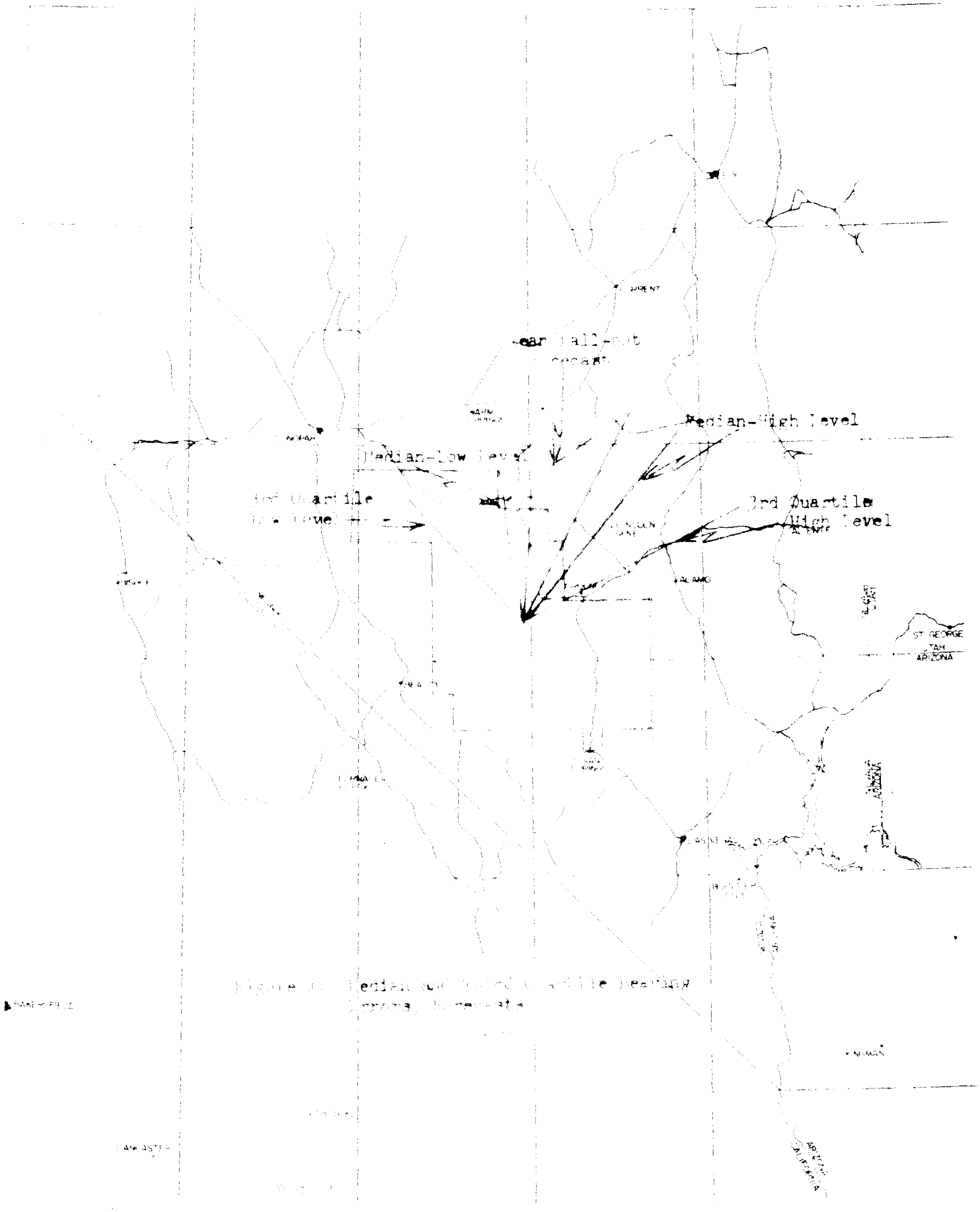


Figure [illegible]. Median and 3rd Quartile Bearing
[illegible]

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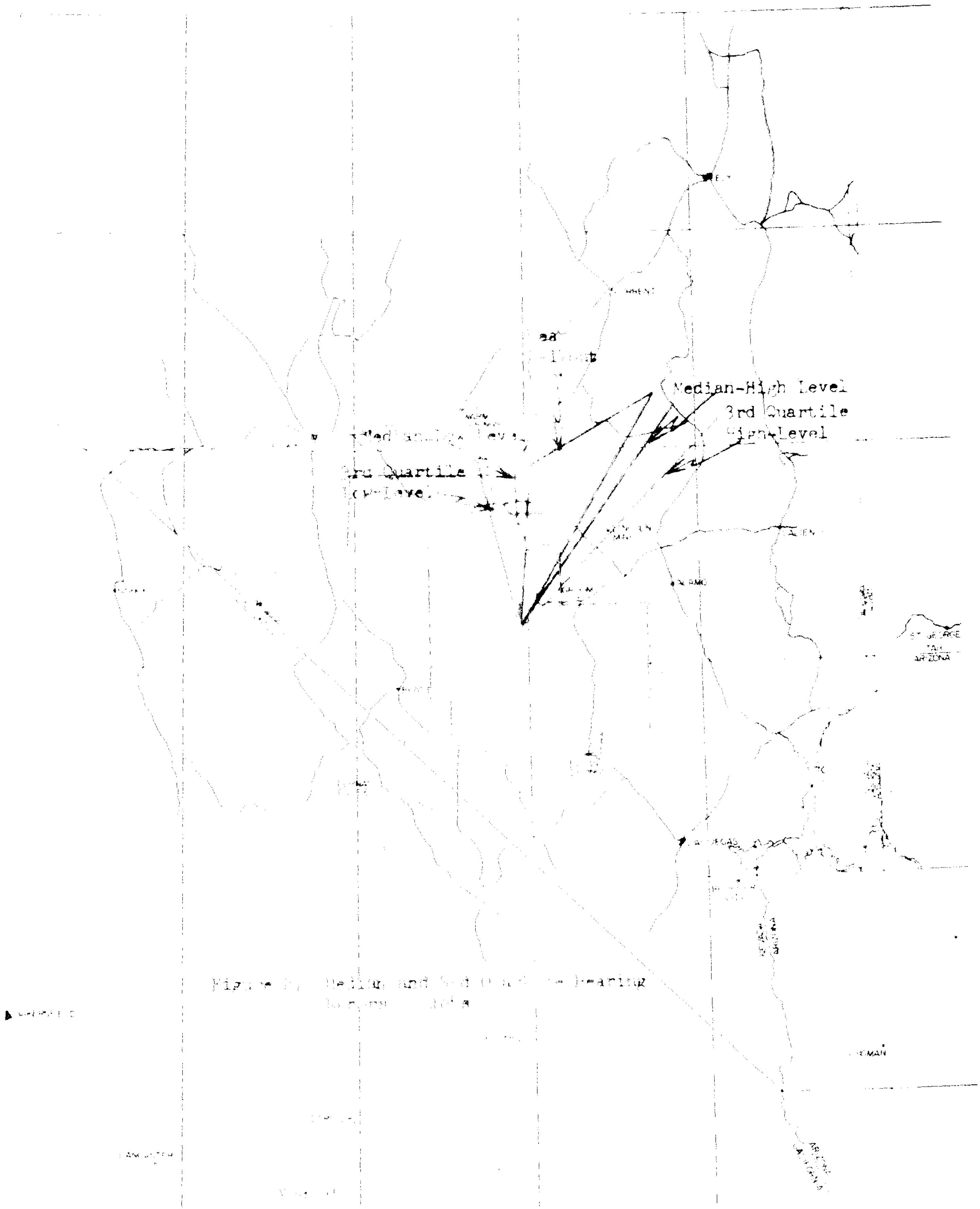


Figure [illegible] Median and 3rd Quartile Bearing [illegible]

[redacted]

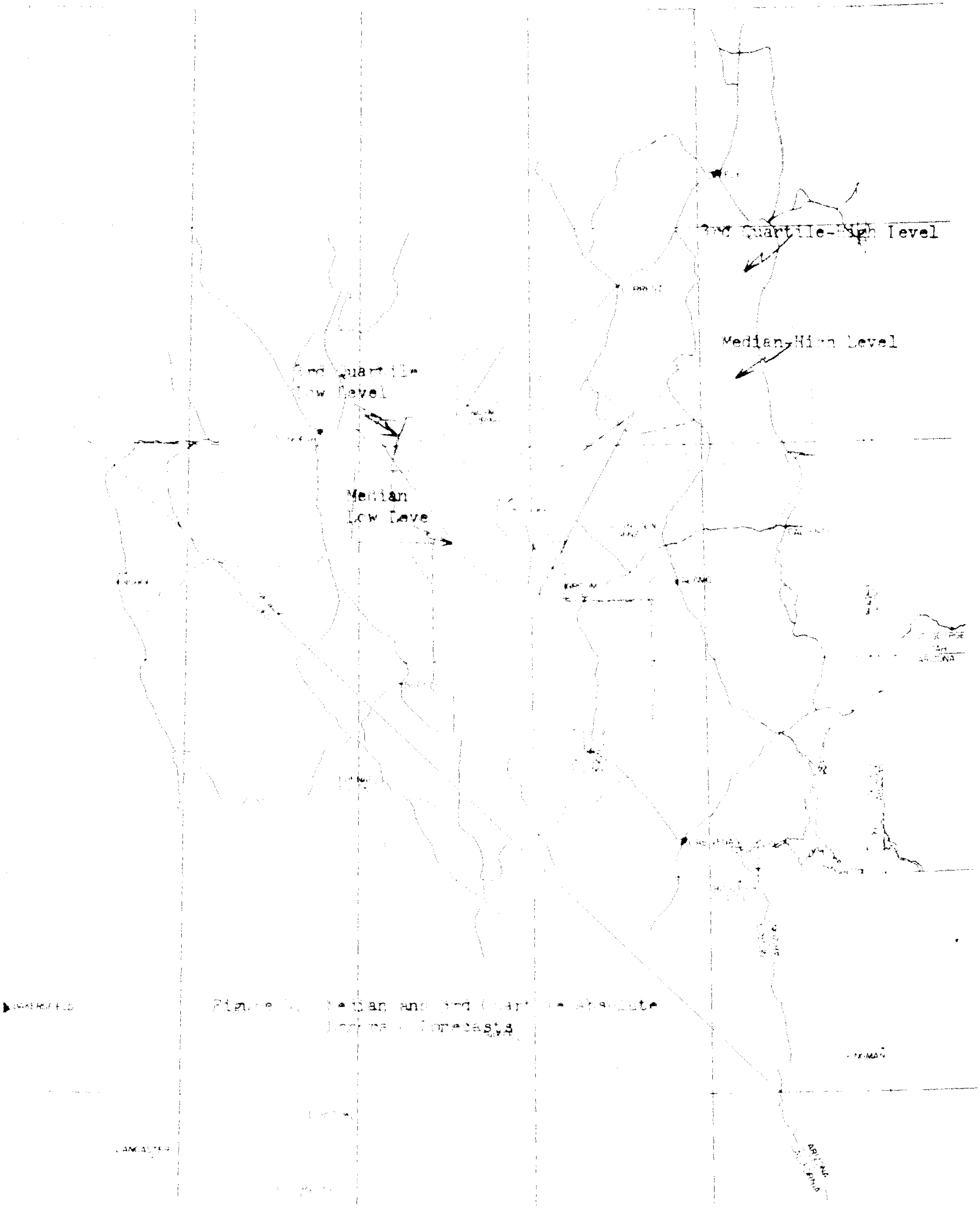


Figure [illegible] Median and 3rd Quartile Absolute Errors - Forecasts

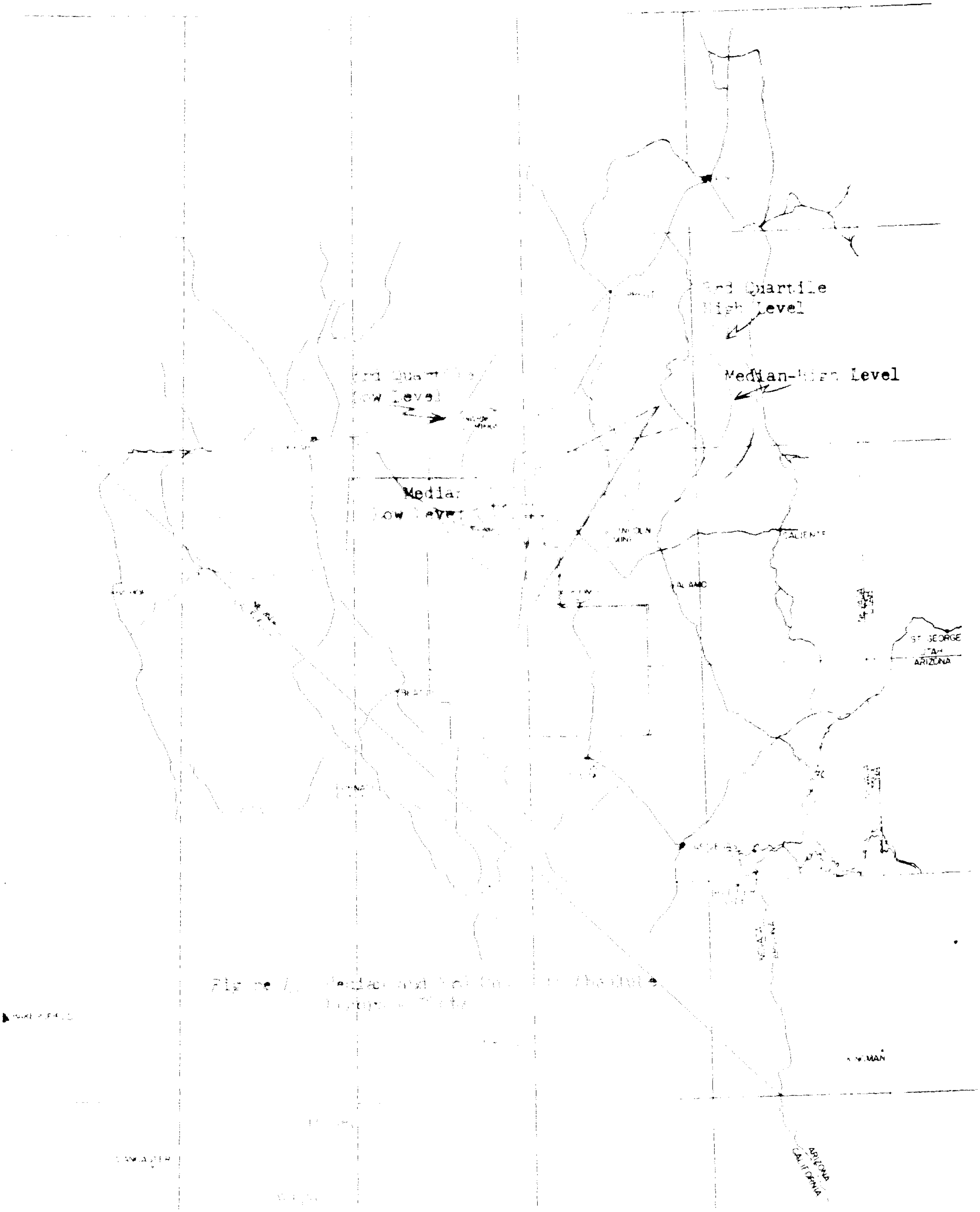
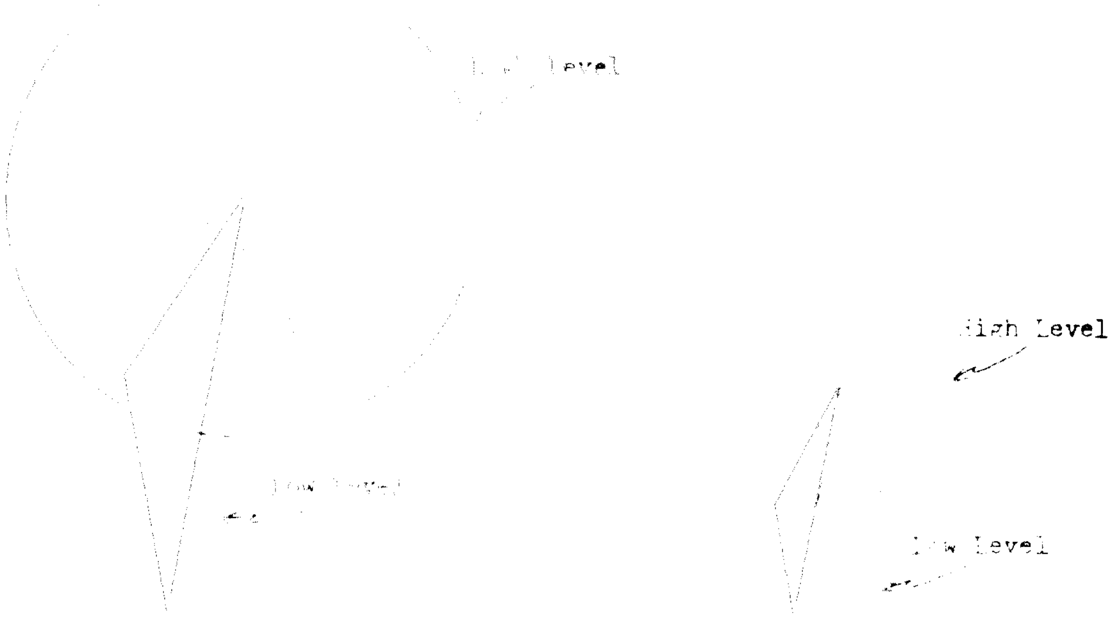
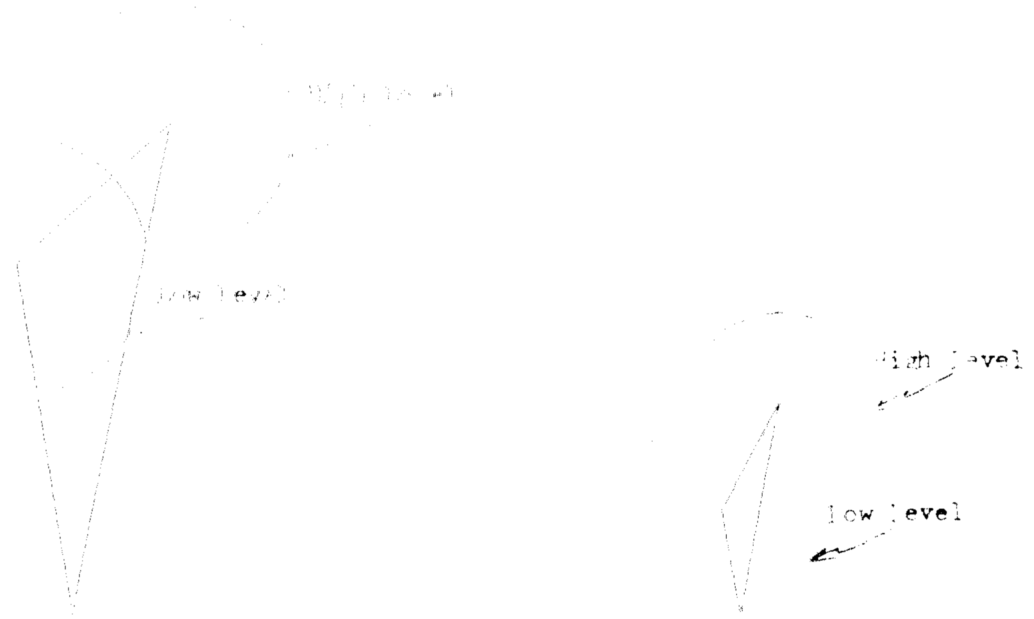


Figure 7. Median and 3rd Quartile Absolute
[illegible]



Heavy Wind Forecast

Light Wind Forecast



Heavy Wind Plot

Light Wind Plot

Figure 4. [illegible] Shapes to be [illegible] Applied on the Mean Fall-out Patterns for [illegible]

TABLE I-2

SURFACE CONTAMINATION T/SI

F	12	4	Station	D/M/ft^2
		✓	CP	2.06×10^6
			Mercury	23,000
✓		✓	Indian Springs	262
✓			Las Vegas	330
✓			Nellis AFB	4,730
	✓		Glendale Junction	5,500
	✓	✓	Alamo	582,000
	✓	✓	Crystal Springs	2.38×10^6
	✓	✓	Caliente	2.04×10^6
	✓	✓	Pioche	2.6×10^6
	✓		Ely	486,000
	✓		Currant	615,000
	✓		Tonopah	2,320
	✓		Beatty	378
	✓	✓	Groom Mine	4.95×10^6
	✓		Lincoln Mine	250,000
1774	1.26×10^6	2.09×10^6		

TABLE II-2

SURFACE CONTAMINATION T/S II

			Station	D/M/ft^2
	✓	✓	CP	12.6 x 10^6
	✓		Mercury	44,400
✓	✓	✓	Indian Springs	5.05 x 10^6
✓			Las Vegas	236,000
✓			Nellis AFB	32,800
			Alamo	2,660
			Caliente	2,880
			Pioche	1,370
			Ely	10,500
			Currant	676
			Warm Springs	970
			Beatty	1,510
			Groom Mine	1,150
			Lincoln Mine	262
			Death Valley Junction	22,400
			Tonopah	Trays lost in high winds
?	5.90	5.90	Glendale Junction	Only one tray exposed. This was radioautographed with no particles resulting and therefore not counted.
			Crystal Springs	Adhesive not applied to trays so no further analysis performed.

TABLE III-3

SURFACE CONTAMINATION T/S III

F	P	A	Station	D/M/ft^2
✓	✓		CP	44,000
✓	✓		Mercury	12,700
✓	✓		Indian Springs	51,200
		✓	Las Vegas	19,500
		✓	Nellis AFB	4,260
		✓	Glendale Junction	3,360
		✓	Alamo	3,380
			Crystal Springs	17,300
			Caliente	13,200
			Pioche	Trays lost
			Ely	5,040
			Currant	31,200
			Warm Springs	5,350
			Tonopah	12,400
	✓		Beatty	2,320
			Groom Mine	960
			Lincoln Mine	970
			Pahrump	1,910
			Lathrop Wells	7,550
[illegible]	28000	7600		

TABLE IV-2

SURFACE CONTAMINATION T/S IV

F	D	A	Station	D/M/ft^2
			CP	650
			Mercury	3,750
			Indian Springs	4,470
			Las Vegas	2,500
			Nellis AFB	1,000
			Glendale Junction	587
✓	✓	✓	Alamo	829,500
✓	✓	✓	Crystal Springs	26,800
✓	✓	✓	Caliente	216,700
✓	✓	✓	Pioche	86,300
		✓	Ely	19,100
			Currant	17,100
			Warm Springs	1,250
			Tonopah	1,785
			Beatty	2,800
✓	✓	✓	Groom Mine	2.5×10^6
✓	✓	✓	Lincoln Mine	4,400
6.1×10^5	61	53		

TABLE V-2

SURFACE CONTAMINATION T/S V

			Station	D/M/ft^2
			CP	71,000
			Mercury	1.8×10^6
			Las Vegas	240,000
			Nellis AFB	8.4×10^6
			Glendale Junction	9,400
			Alamo	423,000
			Crystal Springs	2,600
			Caliente	26,000
✓			Pioche	3.5×10^6
✓	✓	✓	Ely	110×10^6
			Beatty	182,000
✓			Groom Mine	94,500
✓	✓	✓	Lincoln Mine	$2,420 \times 10^6$
			Indian Springs	Trays lost in high winds
✓	✓		Currant	
			Warm Springs	
			Tonopah	

623

265

TABLE VI-2

SURFACE CONTAMINATION T/S VI

E	P	A	Station	D/M/ft²
			CP	9.8×10^6
			Mercury	2.9×10^6
			Indian Springs	4.6×10^6
			Las Vegas	9.4×10^6
			Nellis AFB	271×10^3
			Glendale Junction	[illegible]$.8 \times 10^6$
✓		✓	Alamo	16.5×10^6
✓			Crystal Springs	236×10^6
✓		✓	Caliente	258×10^6
✓		✓	Pioche	1.35×10^9
✓	✓		Ely	413×10^3
✓	✓		Currant	30×10^6
✓			Warm Springs	2.4×10^6
			Beatty	11.2×10^6
✓	✓	✓	Groom Mine	13.1×10^9
✓	✓		Lincoln Mine	158×10^6
✓	✓		North of Pioche	25.6×10^6
1.09	2.7	3.0		

TABLE VII

SURFACE CONTAMINATION T/S VII

F P A

Station	D/M/ft^2
CP	384×10^3
Mercury	43.5×10^3
Indian Springs	55×10^3
Las Vegas	43×10^3
Nellis AFB	64×10^3
Glendale Junction	34×10^3
Alamo	123×10^3
Crystal Springs	26×10^3
Caliente	131×10^3
Pioche	16×10^6
Ely	463×10^3
Currant	125×10^3
Warm Springs	447×10^3
Beatty	76×10^3
West of Currant	3.5×10^9
North of Crystal Springs	34×10^3

0.5 1169.0 875

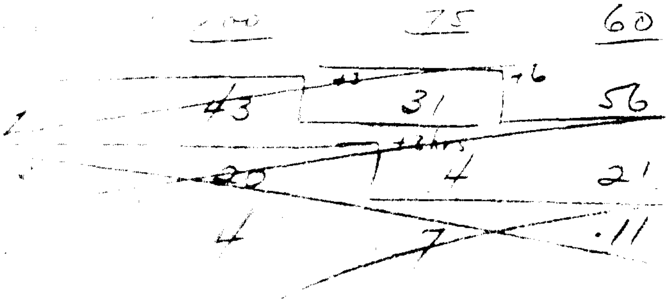
TIME TO FALL FROM LEVEL INDICATED TO A 5000 PLAIN IN HOURS

μ

Elevation	[illegible]	100	75	60
40000'	[illegible] 7	3.8	7.0	10.9
37500'	[illegible]	3.6	6.5	10.2
35000'	[illegible]	3.3	6.0	9.4
32500'	1.3	3.0	5.5	8.6
30000'	1.2	2.8	5.0	7.8
27500'	[illegible]	2.5	4.5	7.0
25000	[illegible]	2.2	4.0	6.2
22500'	[illegible]	1.9	3.5	5.5
20000	[illegible]	1.6	3.0	4.7
17500	[illegible]	1.4	2.5	3.9
15000	[illegible]	1.1	2.0	3.1
12500	[illegible]	0.8	1.5	2.3
10000'	2	0.6	1.0	1.6
7500'	0.1	0.3	0.5	0.8

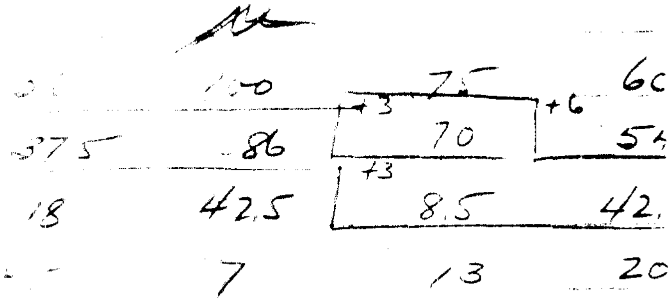
6-9 3-6

21.7 12.3 14.3
65 37 43 ~~42500~~
8.3 0.3
25 31 4 47500
4 12500



VII

6-9 3-6 0-3
20.7 28.0 28.7
62 84 86 32500
17.0 22.7
51 67 22500
26 12500



VIII

9+ 6-9 3-6 0-3
22.3 23.0
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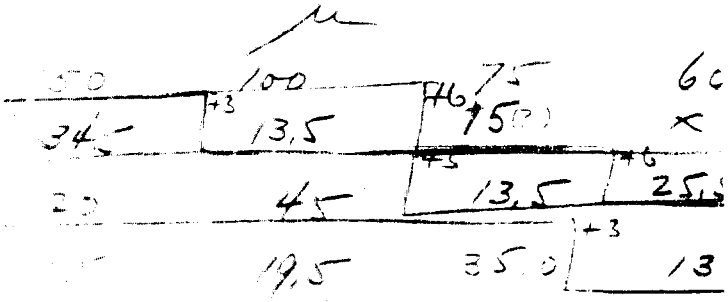
25.7 19.0 18.0
77 57 54 27500
24.3 14.3
73 43 42 17500



VI

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4.0
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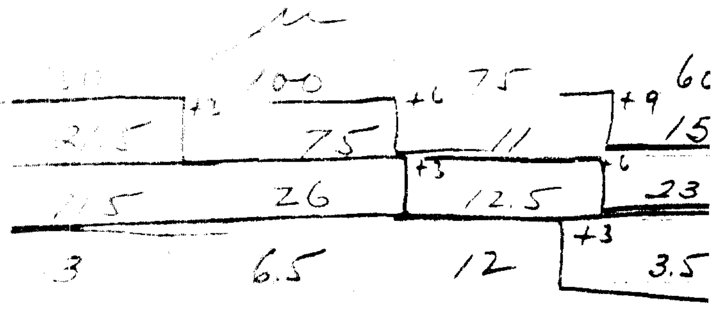

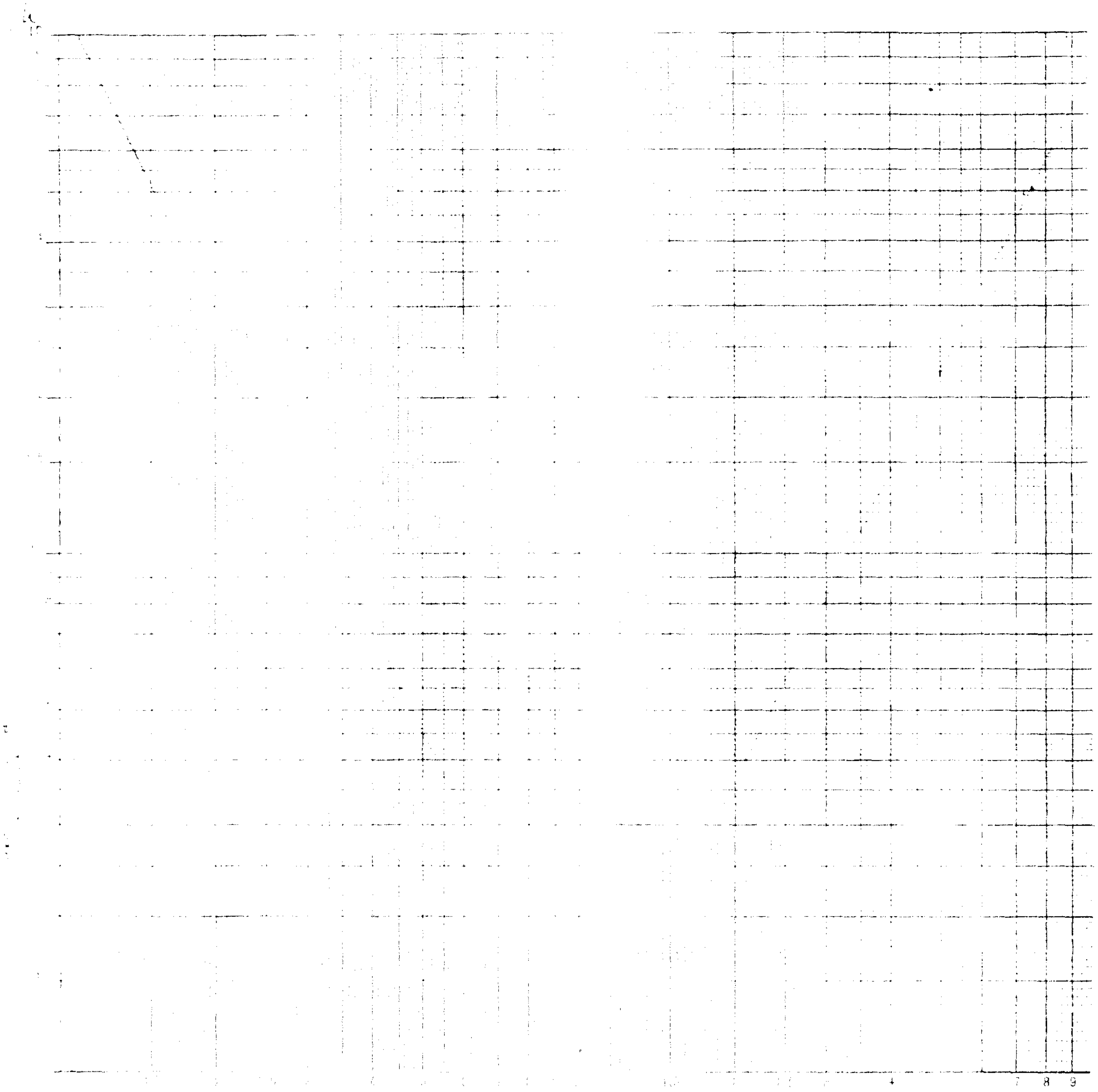
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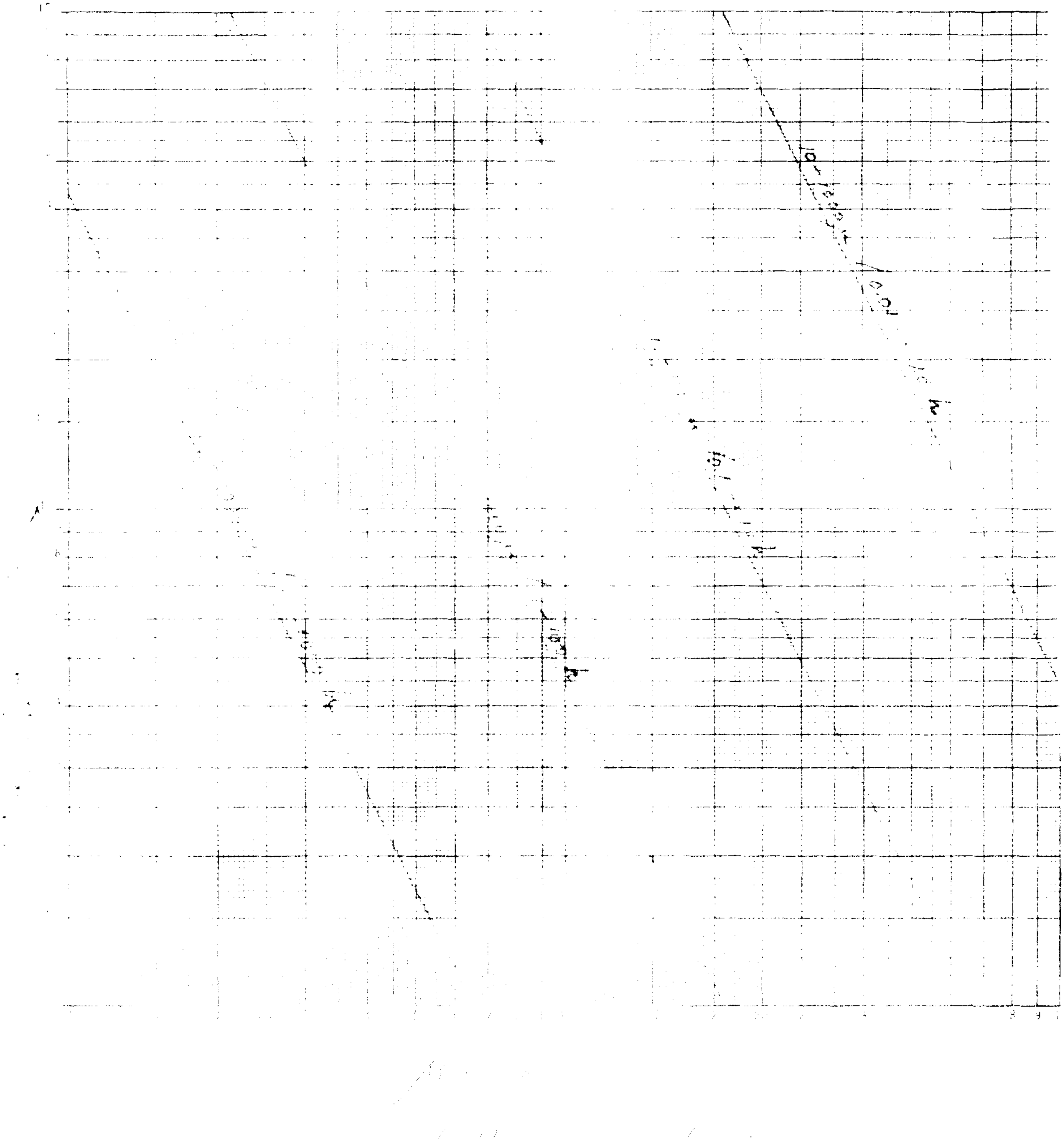
Head of fall in feet