



*The World Leader in Vibrating Wire Technology*

48 Spencer Street  
Lebanon, NH 03766, USA  
Tel: 603•448•1562  
Fax: 603•448•3216  
E-mail: [geokon@geokon.com](mailto:geokon@geokon.com)  
<http://www.geokon.com>

*Instruction Manual*

# Model 4651

## VW Settlement Profiler



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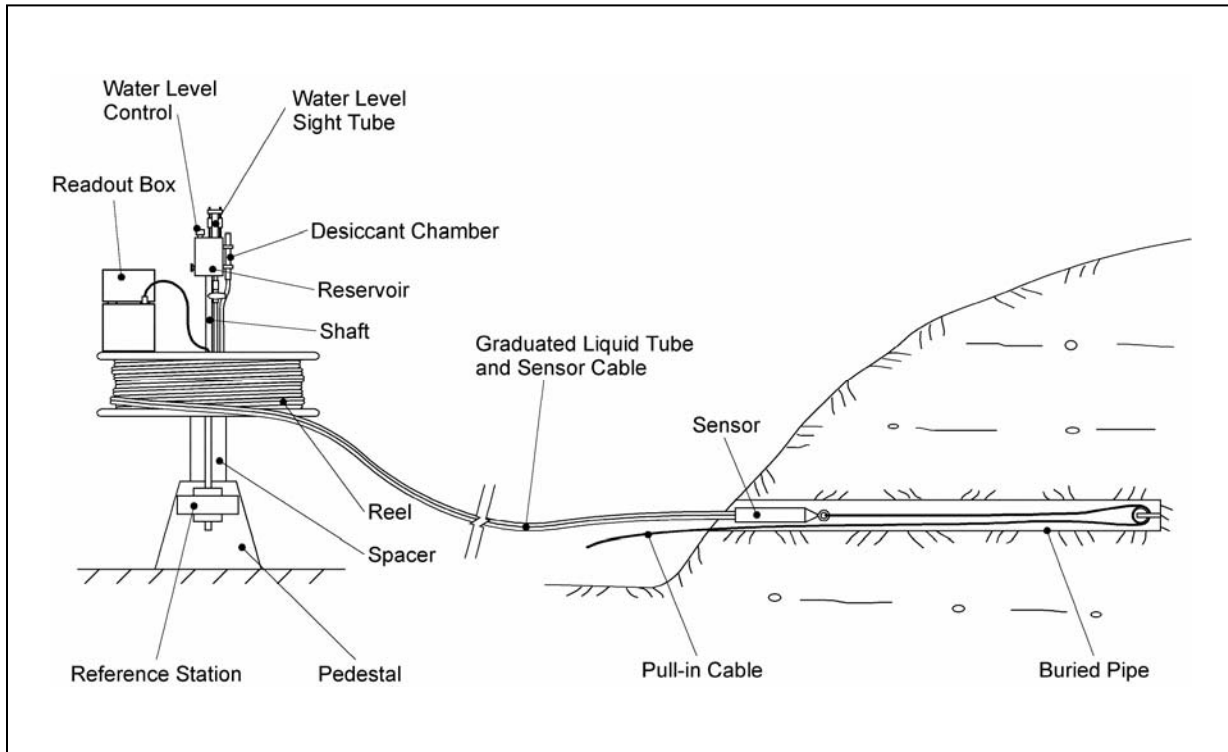
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## 1. Introduction

The Model 4651 Vibrating Wire Settlement Profiler is shown schematically in Figure 1. It consists of a vibrating wire pressure sensor, a liquid-filled tube mounted on a portable reel, a reservoir with sight tube, and a vented signal cable leading from the sensor to a readout box.



*Figure 1. Typical Assembly – Model 4651 V.W. Settlement Profiler.*

In use, the reel is mounted on a pedestal located on solid ground, and is free to turn as the sensor and liquid tube is pulled along a buried pipe, or as the sensor is carried from location to location. The sensor accurately measures the height of the liquid column between the sensor and the reservoir at any point along the buried pipe. The liquid-filled tube is graduated in either meters or feet so that the sensor can be located accurately and repeatedly inside the buried pipe. Provision must be made to enable the sensor to be pulled into the pipe. This will require a pull-in cable passing over some kind of pulley arrangement at the far end of the pipe.

The vibrating wire sensor is vented to atmosphere through the signal cable so that it is not affected by barometric pressure fluctuations. A desiccant chamber is mounted on the end of the vent tube to prevent moisture from reaching the sensor.

## 2. Installation

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### 2.1. Buried pipe requirements

Buried pipes are best made from ABS or PVC plastic, 50mm. (2 inch) internal diameter or larger. A pull-in cable must be installed inside the pipe. Any pulley system must be designed so that the cable cannot slip off the pulley and become jammed; a simple round bar is usually better than a pulley. Alternatively, a second pipe of the same or smaller diameter can be laid alongside the first pipe and connected to it by a U connector. If the far end of the pipe is accessible a second person can assist by pulling the sensor through the pipe from the far end. When not in use always secure the ends of the pull-in cable to some large object, which cannot be pulled inside the pipe.

### 2.2. Above-ground stations

If the settlement stations are above ground some provision must be made to ensure that the sensor is positioned precisely at the same location during each settlement profile survey. Either a hook, from which the sensor can be suspended, or a horizontal piece of pipe, (approx. 75mm. (3 inch) I.D.), in which the sensor can be placed, is acceptable.

### 2.3. Preliminary checks

The Settlement Profiler is shipped with the liquid tube filled with a de-aired anti-freeze solution. There should be no air bubbles inside the liquid tube. Un-reel the liquid tube and inspect for air bubbles. If any are found “chase” them back to the reservoir by elevating the tube ahead of the bubble and by rapping on the tube. Air bubbles inside the liquid tube will reduce the accuracy of the measurements.

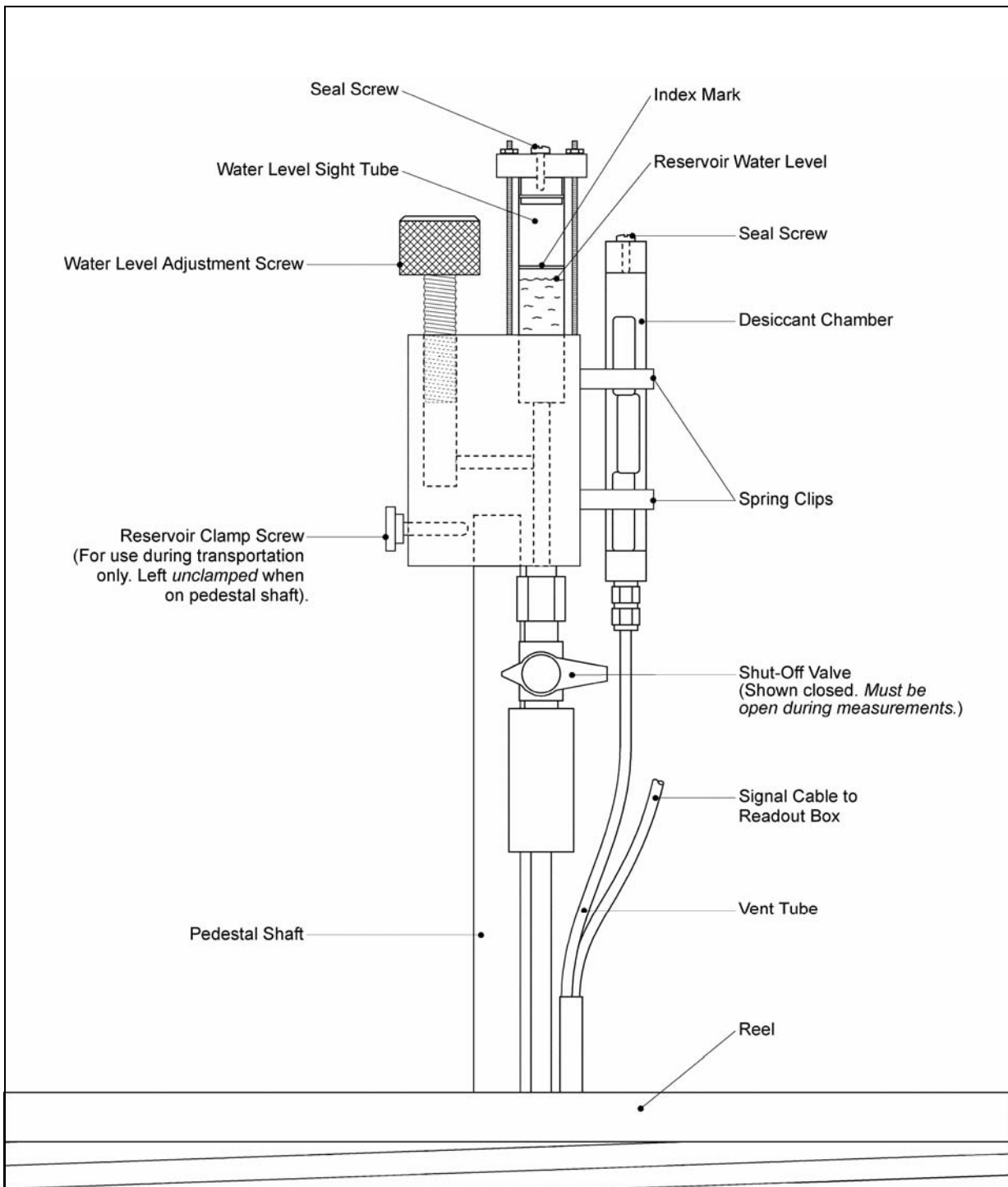
### 2.4. Pedestal Requirements

The concrete pedestal should be located on stable ground, if possible, and the reel elevation needs to be higher than any point along the buried pipe, or, higher than any sensor station in an above ground survey.

The reel is designed for mounting on a vertical shaft, supplied by Geokon, made from two lengths of 13/16inch, (21mm), rod - one 2ft long the other 1ft long.. These two rods should be threaded together and the lower 1 ft piece should be cast inside the concrete pedestal when it is poured. Keep the rod joint flush with the top surface of the pedestal. The PVC spacer and 2 inch washers, also supplied by Geokon are positioned between the reel and the top of the pedestal, (see Figure 1). If necessary the protruding 2ft length of rod can be removed between surveys by unscrewing it from the grouted-in rod. A ½-13 hex-head bolt is supplied to tighten into the thread to keep it clean. Also mounted on the pedestal there needs to be a reference station, either in the form of a hook, from which the sensor can be suspended vertically, or in the form of a length of pipe, mounted horizontally, some 300mm. (12 inch) long and 38mm. (1.5 inch) I.D. into which the sensor can be placed.

### 2.5. Mounting the Reel and Reservoir

The reel is shipped and transported with the reservoir clamped to a bracket inside the reel. The reservoir is freed from the bracket by releasing the knurled clamping screw on the side of the reservoir. Slip the reel over the pedestal shaft, with the spacers in place, then slip the reservoir over the end of the shaft as shown in Figure 2.



**Figure 2. Reservoir Details.**

*Do not clamp the reservoir to the shaft since it needs to turn with the reel. Make sure that the shaft is bottomed-out inside the reservoir recess.*

### 3. Taking Reading ---

#### 3.1. Reference Station Readings

Take the sensor and place it inside the reference station on the side of the pedestal. (Or hang it vertically from the reference hook.) Connect the red and black conductors of the sensor cable to the GK-401, GK-403 or GK-404 Readout Box patchcord, color to color, or, if there is a connector on the sensor cable plug it directly into the “Transducer” plug on the readout box. Position the readout box on top of the reel so that it can turn with the reel. (A slip-ring option is available: consult the factory for details.) Switch the readout box “Display” switch to position B. Open the shut-off valve on the base of the reservoir and open both seal-screws, one on top of the water level sight-tube and the other on top of the desiccant chamber. ***It is essential that these seal-screws be open whenever readings are taken.*** The purpose is to balance the air pressure on the surface of the water inside the reservoir, and the air pressure on the inside of the sensor, so that the sensor is not affected by barometric pressure changes. Turn the seal-screws several turns, until they are quite loose, without becoming totally loose and, maybe, lost.

Use the water level adjustment screw (see Figure 2) to adjust the height of the water level so that it coincides with the index mark on the water level sight-tube. Allow sufficient time for the sensor to achieve temperature stability. When the reading on the readout box becomes stable, record the reading. If a GK403 or GK-404 readout box is in use the temperature is automatically displayed. If a GK401 readout box is in use it will be necessary to read temperatures by connecting a digital ohmmeter to the green and white conductors and then use the table in the Appendix to convert measured resistances to temperatures.

#### 3.2. Conducting the Survey

##### 3.2.1. Buried Pipe Surveys

In buried pipe applications the sensor is attached to the end of the pull-in cable using a snap-swivel on the end of the cable to snap over the eye-bolt on the end of the sensor. The sensor is then pulled to the first readout location using the depth markers on the liquid tube to locate the station. Allow sufficient time for the sensor reading to stabilize, particularly if there are large differences between the borehole temperature and the ambient temperature. Adjust the height of the water level to coincide with the index mark then take readings of pressure and temperature. Pull the sensor to the next readout station and repeat the procedure.

When all the settlement stations have been read, reel in the sensor and once more take readings at the pedestal reference station. Again, allow sufficient time for temperature stabilization. Compare this final reading with the initial reading. If there is a significant difference between the two readings this may be an indication of changing conditions during the survey, and, either the survey needs to be repeated, or the error needs to be distributed evenly amongst the survey readings in accordance with accepted surveying practice.

After all the readings have been taken, return the sensor to the reel, close the valve at the base of the reservoir, close the two seal-screws, then clamp the reservoir to its bracket inside the reel. Disconnect the readout box from the sensor cable.

### 3.2.2. Above-Ground Surveys

Above-ground surveys can be conducted by one person carrying the sensor from station to station while a second person records the readings at the reservoir location. The sensor is sensitive to rapidly changing temperature transients and so it cannot be carried in the bare hands. The sensor must be wrapped in a layer of foam insulation and carried in gloved hands. Experiment to find a method which allows the sensor readings to remain stable. If the ambient temperature changes rapidly during the survey, (as might happen going from indoors to outdoors,) allow sufficient time for the sensor readings to stabilize before continuing with the survey.

The readout stations themselves can be as simple as a hook, from which the sensor can hang, or a piece of horizontal pipe into which the foam-covered sensor will fit. If hooks are used, make sure that the sensor is not pulled away from the vertical by the rest of the liquid tube.

## 4. Data Reduction

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### 4.1. Calculation of Elevation

Ignoring temperature effects, the elevation of the sensor,  $E$ , is given by the equation:

$$E = E_{\text{ref}} - (R_o - R_c) G$$

Where:

- $E_{\text{ref}}$  is the elevation of the pedestal station. (determined by normal surveying.)
- $R_o$  is the reading at the reference station. (Expressed in readout digits)
- $R_c$  is the current reading at the current sensor station. (Readout digits)
- $G$  is the calibration constant. (Expressed in mm./digit, or, inches/digit.)

The calibration constant is obtained from the calibration sheet supplied with the Settlement Profiler. A typical calibration sheet is shown in Figure 3.

#### **Example:**

For a sensor whose calibration factor  $G = 0.001368$  meters/digit, and where  $E_{\text{ref}} = 581.123$  meters,

*During the initial survey:*  $R_o = 9812$ ,  $T_o = 23^\circ\text{C}$ ,  $R_c$  (at St. 1) = 7540,  $T_c = 10^\circ\text{C}$

*During the second survey:*  $R_o = 9830$ ,  $T_o = 15^\circ\text{C}$ ,  $R_c$  (at St. 1) = 7488,  $T_c = 8^\circ\text{C}$

At the time of the initial survey, and ignoring temperature effects:

$$E = 581.123 - (9812 - 7540)(0.001368) = 578.015 \text{ meters}$$

At the time of the second survey:

$$E = 581.123 - (9830 - 7488)(0.001368) = 577.919 \text{ meters}$$

Indicating an apparent settlement at station 1 of 96mm.

#### 4.2. Correction for Temperature

The correction for temperature is as follows:

$$E_{\text{corr}} = E_{\text{ref}} - (R_o - R_c) G + (T_c - T_o) K$$

Where:

$E_{\text{corr}}$  is the elevation of the sensor location

$E_{\text{ref}}$  is the elevation of the pedestal station

$R_o$  is the reading at the reference station (readout digits, channel B)

$R_c$  is the reading at the sensor location

$G$  is the calibration constant in mm/digit or inches/digit

$T_c$  is the temperature reading at the station, °C

$T_o$  is the temperature reading at the reference station, °C

$K$  is the sensor Thermal Correction Factor given on the calibration sheet in mm /°C or inches /°C

*Example: Using the data already supplied and where*

$$K = -0.514 \text{ mm/}^\circ\text{C}$$

Initial survey at station 1:

$$E_{\text{corr}} = 578.015 + (10 - 23) (-0.000514)$$

$$E_{\text{corr}} = 578.015 + 0.007$$

$$E_{\text{corr}} = 578.022$$

Second survey at station 1:

$$E_{\text{corr}} = 577.919 + (8 - 15) (-0.000514)$$


$$E_{\text{corr}} = 577.919 + 0.004$$

$$E_{\text{corr}} = 577.923$$

*i.e.* A settlement at station 1 of 0.99 mm



## Settlement Profiler Calibration Report

Model Number: 4651-1-10 Date: May 3, 1999  
 Serial Number: 48883 Transducer Size: 10 psi (vented)  
 Transducer Number: 8-3628 Cal. Std. Control #(s): 213,405,377  
 Customer I.D. #: n/a Temperature: 24.3 °C  
 Customer: \_\_\_\_\_ Tubing: 300ft.  
 Job Number: 13416 Cable: 300ft.  
 Technician: 

\*tubing filled and gage calibrated with 1:1 mix water/anti-freeze - specific gravity 1.065

Elevation m	Reading GK 401 Pos. B	Difference
0.610	10256.5	
0.914	10033.0	223.5
1.219	9809.5	223.5
1.524	9585.5	224.0
1.829	9363.5	222.0
2.134	9141.0	222.5
2.438	8918.5	222.5

Calibration Factor, G, = 1.368 mm per digit

Thermal Factor, K, = -3.76 digits/°C

= -5.14 mm/°C

DO NOT EXCEED 7 m (23 Feet) BETWEEN RESERVOIR & TRANSDUCER

Wiring Code: Red and Black: Gage White and Green: Thermistor

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

Figure 3, Typical Calibration Sheet.

## 5. Troubleshooting and Maintenance \_\_\_\_\_

The sensor is a precision instrument and should be treated with care at all times; jarring of the sensor can cause zero shifts. Note also that the sensor has a maximum range of 7 meters (standard range), i.e. this is the maximum allowable elevation of the reservoir above the sensor.

The main problem, typical of all liquid level devices, will be air bubbles inside the liquid tube, which will cause fluctuating, unstable, or non-repeating readings. Examine the liquid tube for air bubbles and remove as described in Section 2.3.

If no readings can be obtained, check the resistance between the red and black connectors; the resistance should be 180 ohms +/- 10 ohms. The resistance between the green and white conductors (thermistor) should be around 3000 ohms depending on the temperature and consistent with the table given in the Appendix.

Unstable readings can be caused by electrical interference from nearby electrical equipment and power lines. This problem can often be corrected by connecting the blue alligator clip of the GK401, GK-403 or GK404 readout box patch-cord to the cable shield wire.

Where a 10 pin connector has been attached to the cable the pin-out is as follows:

Pin	Color	Function
A	red	gage
B	black	gage
C	white	thermistor
D	green	thermistor
E	shield	ground

The desiccant capsules, in the desiccant chamber, will require changing from time to time: active capsules are blue, spent capsules are pink. Fresh capsules are available from Geokon.

In-situ calibrations can be performed from time to time simply by raising the reservoir a known, measured amount and recording the corresponding change in reading of the sensor.

With very long profilers it sometimes will happen that the water level in the reservoir cannot be made to align with the index mark even with the water level control screw screwed all the way in. If this is the case just back off the screw and add more water to the reservoir.

## 6. Specifications

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<b>Range (standard)<sup>1</sup></b>	7 meters (20 feet)
<b>Sensitivity (standard)</b>	1.5 mm (0.06 inches)
<b>Accuracy (standard) **</b>	0.1% F.S.
<b>Linearity (standard)</b>	0.15% F.S.
<b>Temperature Range</b>	- 20°C to +50°C
<b>Frequency Range</b>	1400-3500Hz
<b>Thermal Coefficient</b>	0.05% F.S./°C (typical)
<b>Dimensions</b>	
<i>Sensor</i>	35 mm (1 3/8") diameter
<i>Reel</i>	650 mm (24") diameter
<b>Liquid - Tube Length<sup>2</sup></b>	100 meters max. (330 feet)
<b>Buried Pipe Diameter</b>	50 mm (2") I.D.
<b>Cable Connector</b>	10 pin Bendix PTO6A -12 -10 P (SR)
<b>Readout Device</b>	Geokon Model GK-403 or GK-401

<sup>1</sup>Other ranges available on request

<sup>2</sup>Liquid tube length to be specified when ordering

\*\* This is the accuracy of the transducer calibration. The system accuracy will be closer to 0.25% FS.

Appendix A: \_\_\_\_\_

Thermistor Linearization using Steinhart and Hart Log Equation

Tech Memo 91-03 Doc Rev 6-94, Geokon, Inc.

**Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3**

**Basic Equation:** 
$$T = \frac{1}{A + B(\ln R) + C(\ln R)^3} - 273.2$$

where:

**T** = Temperature in °C.

**LnR** = Natural Log of Thermistor Resistance

**A** =  $1.4051 \times 10^{-3}$

**B** =  $2.369 \times 10^{-4}$

**C** =  $1.019 \times 10^{-7}$

*Note: Coefficients calculated over -50° to +150° C. span.*

**Resistance versus Temperature Table**

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	<b>3000</b>	<b>25</b>	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150