



# Identification of Seasonal Effects through Ratio to Moving Average Method for the Ground Water Levels in Anantapuramu District

\*<sup>1</sup>Raju Sake

\*<sup>1</sup>Academic Consultant, Department of Statistics, Sri Krishnadevaraya University, Anantapuramu, Andhra Pradesh, India.

## Abstract

Earlier the authors worked on Trend effects and Seasonal effects on Ground Water Levels (GWLs) in Anantapuramu district, for the data collected from January 2001 to November 2017. While calculating trend values we have used different linear and non-linear models like, Straight line, Parabola, Exponential, Power curve models. Similarly to determine Seasonal effects we have used

- i). Simple Averages Method and
- ii). Ratio to Trend Method.

Now we proceed to determine Seasonal effects through an improved method over Simple Averages and Ratio to Trend Method namely 'Ratio to Moving Average Method'. Conclusions are drawn based on the results obtained.

**Keywords:** Ratio to moving average method, simple averages method, ratio to trend method, seasonal effects, trend effects

## Introduction

Ground Water Levels is the most important for farmers in agricultural and future plans for improving existing facilities. So we have collected data from year January 2001 to November 2017 in Anantapuramu District of A.P. In earlier papers we have determine trend values through linear and non-linear models like, Straight line, Parabola, Exponential and Power curve and identified 'Parabola' trend model is the best model. Further our concentration is diverted towards the determination of Seasonal effects on the variables under consideration using Simple Averages Method and Ratio to Trend Method.

In the present paper an improved method namely, 'Ratio to Moving Average Method' is applied and determine the Seasonal Indices for Ground Water Levels in Anantapuramu District. Now we proceed to explain some preliminaries of Ratio to Moving Averages Method and some relevant definitions required to obtain the results of Seasonal Indices in the following section.

## Methodology

Earlier, it is mentioned that Seasonal Indices can be calculated by using the following four methods.

- i). Method of simple averages
- ii). Ratio to trend method
- iii). Ratio to moving average method and
- iv). Link relative method.

Determination of Seasonal Indices through method of Simple Averages has a major drawback or disadvantage that this method is more depending on extreme values that is averages gives more weightage to extreme values which are not primarily due to Seasonal Variations. These effects can be explained clearly as follows:

Due to Natural Calamities like., Floods is came on that moment Ground Water Levels are huge from bottom position to upward position Ground Water Levels may increase abruptly in Earth. In those situations these effects are not called Seasonal effects; this is called Cyclical/Random effects because Seasonal effects are those effects whose period is less than one year and the period should occur in equal intervals.

**For Example:** In Rainy Season or Monsoon Seasons like, South-West Monsoon and North-East Monsoon Ground Water Levels is huge. In Summer Season or Hot Winter Season Ground Water Levels is very less that means the Ground Water levels are going deeper and deeper from top position to bottom position in the Earth. These can be considered as Seasonal effects.

Now we proceed to explain some preliminary definitions, terms used in calculating Seasonal Indices in Ratio to Moving Average Method.

This method is an improvement over the simple averages method and Ratio to Trend Method and is based on the assumption that seasonal variation for any given month is constant factor of the trend. The measurement of seasonal variation by this method consists on the following steps:

As pointed out earlier moving averages eliminates periodic movements if the extent (period of moving average is equal to the period of the oscillatory movements sought to be eliminated). Thus for a monthly data, a 12 month moving average should completely eliminate the seasonal movements if they are of constant pattern and intensity. The method of getting seasonal indices by moving average involves the following steps:

**Step-I:** Calculate the centered 12 month moving average of the data. These moving average values will give estimates of the combined effects of trend and cyclic variations.

**Step-II:** Express the original data (except for 6 months in the beginning and 6 months at the end) as percentages of the centered moving average values. Using multiplicative model, these percentages would then represent the seasonal and irregular components.

**Step-III:** The preliminary seasonal indices are now obtained by eliminating the irregular or random component by averaging these percentages. As discussed in Ratio to Trend Method, step (iii), either arithmetic mean or median (preferably median) can be used for averaging.

**Step-IV:** The sum of these indices = S (say) will not, in general, be 1200. Finally an adjustment is done to make the sum of the indices 1200 by multiplying throughout by a constant factor = 1200/S, i.e., by expressing the preliminary seasonal indices as the percentage of their arithmetic mean. The resultant gives the desired indices of seasonal variations.

#### Merits and Demerits

Of all the methods of measuring seasonal variations, the ratio to the moving average method is the most satisfactory, flexible and widely used method. These indices do not fluctuate as much as the indices by the ratio to trend method.

#### Data and Calculations (Quarter-Wise)

Table 1: Ratio to Moving Average Method for GWLs in Zone-I

Years	Quarters	GWLs ( $U_t$ )	4-Quarterly Moving Totals	4-Quarterly Moving Averages	Centered Averages ( $T_t$ ) or Moving Average	$\frac{U_t}{T_t} \times 100$	Trend Eliminated Values ( $U_t - T_t$ )
2001	$Q_1$	25.05					
	$Q_2$	28.90					
	$Q_3$	31.77	100.21	25.05	24.22	131.19	7.55
	$Q_4$	14.49	93.52	23.38	22.67	63.92	-8.18
2002	$Q_1$	18.36	87.82	21.96	21.29	86.25	-2.93
	$Q_2$	23.20	82.48	20.62	22.31	103.97	0.89
	$Q_3$	26.43	96.03	24.01	26.59	99.42	-0.15
	$Q_4$	28.04	116.65	29.16	31.23	89.79	-3.19
2003	$Q_1$	38.98	133.17	33.29	35.46	109.93	3.52
	$Q_2$	39.72	150.49	37.62	39.17	101.42	0.56
	$Q_3$	43.75	162.83	40.71	41.24	106.09	2.51
	$Q_4$	40.38	167.07	41.77	42.51	94.99	-2.13
2004	$Q_1$	43.22	173.01	43.25	42.92	100.70	0.30
	$Q_2$	45.66	170.34	42.59	42.68	106.99	2.98

This method does not completely utilize the data, e.g., in the case of 12-month moving average seasonal indices cannot be obtained for the first 6-months and for the last 6-months.

#### Remarks

**1. Specific Seasonal Index and Typical Seasonal Index:** Seasonal Index: The seasonal indices for each month (quarter) of different years are also known as specific seasonal and the average of specific seasonal for each month (quarter) for a number of years are termed as typical seasonal.

**2. Additive Model:** If we use additive model of the time series, then the method of moving averages for computing seasonal indices involves the following steps. [We shall state the steps for monthly data and these can be modified accordingly for quarterly and other data]

- Obtain 12-month moving average values. These will contain trend and cyclic components, i.e. they will represent (T+C).
- Trend eliminated values are obtained on subtracting these moving average values from the given time series values to give:

$$U_t - \text{M.A. values} = (T+S+C+I)-(T+C) = S+I$$

- Irregular component is eliminated on averaging these (S-I) values for each month over different years and we get the preliminary indices for each month.
- Sum of the indices should be zero. In case it is not so, the preliminary indices in step (iii) are adjusted to a total of zero by subtracting from each of them a constant factor

$$\frac{k}{12} [\text{Sum of monthly seasonal indices}]$$

	$Q_3$	41.08	171.08	42.77	42.67	96.27	-1.59
	$Q_4$	41.12	170.28	42.57	42.79	96.11	-1.67
2005	$Q_1$	42.42	172.01	43.00	43.27	98.04	-0.85
	$Q_2$	47.39	174.12	43.53	41.83	113.31	5.57
	$Q_3$	43.19	160.48	40.12	38.38	112.53	4.81
	$Q_4$	27.48	146.57	36.64	34.75	79.07	-7.27
2006	$Q_1$	28.51	131.46	32.87	32.03	89.02	-3.52
	$Q_2$	32.28	124.76	31.19	32.16	100.38	0.12
	$Q_3$	36.49	132.50	33.13	34.22	106.63	2.27
	$Q_4$	35.22	141.26	35.32	36.25	97.15	-1.03
2007	$Q_1$	37.27	148.77	37.19	36.30	102.67	0.97
	$Q_2$	39.79	141.63	35.41	33.61	118.38	6.18
	$Q_3$	29.35	127.26	31.82	30.44	96.41	-1.09
	$Q_4$	20.85	116.29	29.07	27.95	74.60	-7.10
2008	$Q_1$	26.3	107.29	26.82	27.21	96.67	-0.90
	$Q_2$	30.79	110.35	27.59	28.75	107.11	2.04
	$Q_3$	32.41	119.62	29.91	30.46	106.41	1.95
	$Q_4$	30.12	124.03	31.01	31.76	94.85	-1.64
2009	$Q_1$	30.71	130.01	32.50	33.80	90.85	-3.09
	$Q_2$	36.77	140.40	35.10	35.81	102.67	0.96
	$Q_3$	42.8	146.11	36.53	37.26	114.87	5.54
	$Q_4$	35.83	151.96	37.99	38.94	92.03	-3.11
2010	$Q_1$	36.56	159.52	39.88	39.46	92.66	-2.90
	$Q_2$	44.33	156.13	39.03	38.63	114.75	5.70
	$Q_3$	39.41	152.92	38.23	38.05	103.56	1.36
	$Q_4$	32.62	151.51	37.88	37.07	87.99	-4.45
2011	$Q_1$	35.15	145.06	36.27	36.22	97.05	-1.07
	$Q_2$	37.88	144.69	36.17	37.13	102.03	0.76
	$Q_3$	39.04	152.31	38.08	39.06	99.96	-0.02
	$Q_4$	40.24	160.14	40.04	41.60	96.72	-1.36
2012	$Q_1$	42.98	172.68	43.17	44.32	96.98	-1.34
	$Q_2$	50.42	181.85	45.46	45.26	111.40	5.16
	$Q_3$	48.21	180.22	45.06	44.97	107.20	3.24
	$Q_4$	38.61	179.55	44.89	45.00	85.80	-6.39
2013	$Q_1$	42.31	180.45	45.11	45.78	92.41	-3.47
	$Q_2$	51.32	185.82	46.46	47.17	108.80	4.15
	$Q_3$	53.58	191.54	47.89	48.36	110.79	5.22
	$Q_4$	44.33	195.35	48.84	48.61	91.20	-4.28
2014	$Q_1$	46.12	193.52	48.38	47.81	96.47	-1.69
	$Q_2$	49.49	188.96	47.24	47.64	103.89	1.85
	$Q_3$	49.02	192.14	48.04	48.11	101.90	0.91

	<b>Q<sub>4</sub></b>	47.51	192.71	48.18	48.10	98.78	-0.59
2015	<b>Q<sub>1</sub></b>	46.69	192.05	48.01	47.75	97.78	-1.06
	<b>Q<sub>2</sub></b>	48.83	189.95	47.49	46.07	105.99	2.76
	<b>Q<sub>3</sub></b>	46.92	178.63	44.66	44.19	106.17	2.73
	<b>Q<sub>4</sub></b>	36.19	174.90	43.73	43.90	82.44	-7.71
2016	<b>Q<sub>1</sub></b>	42.96	176.31	44.08	43.99	97.65	-1.03
	<b>Q<sub>2</sub></b>	50.24	175.64	43.91	45.32	110.87	4.93
	<b>Q<sub>3</sub></b>	46.25	186.88	46.72	47.78	96.80	-1.53
	<b>Q<sub>4</sub></b>	47.43	195.35	48.84	49.73	95.37	-2.30
2017	<b>Q<sub>1</sub></b>	51.43	202.50	50.63	51.94	99.03	-0.51
	<b>Q<sub>2</sub></b>	57.39	212.99	53.25	49.99	114.81	7.40
	<b>Q<sub>3</sub></b>	56.74	186.90	46.73			
	<b>Q<sub>4</sub></b>	21.34					

**Table 2:** Computations of Seasonal Indices (S.I)

Years	<b>Q<sub>1</sub></b>	<b>Q<sub>2</sub></b>	<b>Q<sub>3</sub></b>	<b>Q<sub>4</sub></b>
2001	-	-	131.19	63.92
2002	86.25	103.97	99.42	89.79
2003	109.93	101.42	106.09	94.99
2004	100.70	106.99	96.27	96.11
2005	98.04	113.31	112.53	79.07
2006	89.02	100.38	106.63	97.15
2007	102.67	118.38	96.41	74.60
2008	96.67	107.11	106.41	94.85
2009	90.85	102.67	114.87	92.03
2010	92.66	114.75	103.56	87.99
2011	97.05	102.03	99.96	96.72
2012	96.98	111.40	107.20	85.80
2013	92.41	108.80	110.79	91.20
2014	96.47	103.89	101.90	98.78
2015	97.78	105.99	106.17	82.44
2016	97.65	110.87	96.80	95.37
2017	99.03	114.81	-	-
Total	1544.16	1726.77	1696.2	1420.81
Average (P.S.I)	96.51	107.92	106.01	88.80
Adjusted S.I	96.6934	108.1250	106.2114	88.9687

**Table 3:** Computations of Seasonal Indices (S.I) for Trend Eliminated Values

Years	<b>Q<sub>1</sub></b>	<b>Q<sub>2</sub></b>	<b>Q<sub>3</sub></b>	<b>Q<sub>4</sub></b>
2001	-	-	7.55	-8.18
2002	-2.93	0.89	-0.15	-3.19
2003	3.52	0.56	2.51	-2.13
2004	0.30	2.98	-1.59	-1.67
2005	-0.85	5.57	4.81	-7.27
2006	-3.52	0.12	2.27	-1.03
2007	0.97	6.18	-1.09	-7.10
2008	-0.90	2.04	1.95	-1.64
2009	-3.09	0.96	5.54	-3.11
2010	-2.90	5.70	1.36	-4.45

2011	-1.07	0.76	-0.02	-1.36
2012	-1.34	5.16	3.24	-6.39
2013	-3.47	4.15	5.22	-4.28
2014	-1.69	1.85	0.91	-0.59
2015	-1.06	2.76	2.73	-7.71
2016	-1.03	4.93	-1.53	-2.30
2017	-0.51	7.40	-	-
Total	-19.57	52.01	33.71	-62.4
Average (P.S.I)	-1.22	3.25	2.10	-3.9
Adjusted S.I	-1.2775	3.1925	2.0425	-3.9575

**Table 4:** Ratio to Moving Average Method for GWLs in Zone-II

Years	Quarters	GWLs ( $U_t$ )	4-Quarterly Moving Totals	4-Quarterly Moving Averages	Centered Averages ( $T_t$ ) or Moving Average	$\frac{U_t}{T_t} \times 100$	Trend Eliminated Values ( $U_t - T_t$ )
2001	$Q_1$	42.31					
	$Q_2$	44.94					
	$Q_3$	50.91	170.23	42.56	41.40	122.97	9.51
	$Q_4$	32.07	160.96	40.24	39.53	81.13	-7.46
2002	$Q_1$	33.04	155.28	38.82	38.04	86.85	-5.00
	$Q_2$	39.26	149.06	37.27	39.67	98.97	-0.41
	$Q_3$	44.69	168.28	42.07	43.79	102.05	0.90
	$Q_4$	51.29	182.06	45.52	48.78	105.14	2.51
2003	$Q_1$	46.82	208.19	52.05	55.27	84.72	-8.45
	$Q_2$	65.39	233.94	58.49	60.08	108.85	5.32
	$Q_3$	70.44	246.66	61.67	64.00	110.07	6.44
	$Q_4$	64.01	265.32	66.33	66.64	96.05	-2.63
2004	$Q_1$	65.48	267.8	66.95	66.56	98.38	-1.08
	$Q_2$	67.87	264.66	66.17	66.94	101.40	0.94
	$Q_3$	67.3	270.82	67.71	69.26	97.17	-1.96
	$Q_4$	70.17	283.26	70.82	73.04	96.07	-2.87
2005	$Q_1$	77.92	301.08	75.27	76.50	101.86	1.42
	$Q_2$	85.69	310.89	77.72	75.22	113.91	10.47
	$Q_3$	77.11	290.9	72.73	69.46	111.01	7.65
	$Q_4$	50.18	264.81	66.20	62.94	79.73	-12.76
2006	$Q_1$	51.83	238.68	59.67	57.82	89.64	-5.99
	$Q_2$	59.56	223.88	55.97	57.49	103.61	2.07
	$Q_3$	62.31	236.02	59.01	61.36	101.55	0.95
	$Q_4$	62.32	254.87	63.72	65.80	94.71	-3.48
2007	$Q_1$	70.68	271.52	67.88	68.96	102.50	1.73
	$Q_2$	76.21	280.12	70.03	68.89	110.62	7.32
	$Q_3$	70.91	271.02	67.76	67.26	105.43	3.65
	$Q_4$	53.22	267.03	66.76	65.94	80.71	-12.72
2008	$Q_1$	66.69	260.51	65.13	64.37	103.61	2.32

	$Q_2$	69.69	254.42	63.61	62.89	110.81	6.80
	$Q_3$	64.82	248.7	62.18	60.16	107.75	4.66
	$Q_4$	47.5	232.55	58.14	56.35	84.30	-8.85
2009	$Q_1$	50.54	218.23	54.56	53.71	94.10	-3.17
	$Q_2$	55.37	211.45	52.86	52.72	105.02	2.65
	$Q_3$	58.04	210.34	52.59	52.22	111.14	5.82
	$Q_4$	46.39	207.44	51.86	50.98	91.00	-4.59
2010	$Q_1$	47.64	200.39	50.10	48.71	97.80	-1.07
	$Q_2$	48.32	189.31	47.33	46.27	104.44	2.05
	$Q_3$	46.96	180.82	45.21	44.17	106.31	2.79
	$Q_4$	37.9	172.55	43.14	42.81	88.54	-4.91
2011	$Q_1$	39.37	169.89	42.47	42.66	92.29	-3.29
	$Q_2$	45.66	171.4	42.85	44.17	103.36	1.49
	$Q_3$	48.47	181.99	45.50	47.78	101.45	0.69
	$Q_4$	48.49	200.21	50.05	52.08	93.11	-3.59
2012	$Q_1$	57.59	216.4	54.10	56.24	102.40	1.35
	$Q_2$	61.85	233.54	58.39	59.94	103.18	1.91
	$Q_3$	65.61	246	61.50	62.74	104.58	2.88
	$Q_4$	60.95	255.88	63.97	66.26	91.99	-5.31
2013	$Q_1$	67.47	274.18	68.55	69.42	97.19	-1.95
	$Q_2$	80.15	281.19	70.30	69.78	114.85	10.37
	$Q_3$	72.62	277.08	69.27	68.45	106.09	4.17
	$Q_4$	56.84	270.55	67.64	66.14	85.94	-9.30
2014	$Q_1$	60.94	258.54	64.64	65.08	93.64	-4.14
	$Q_2$	68.14	262.1	65.53	67.90	100.36	0.24
	$Q_3$	76.18	281.06	70.27	73.23	104.02	2.95
	$Q_4$	75.8	304.8	76.20	78.51	96.55	-2.71
2015	$Q_1$	84.68	323.25	80.81	82.09	103.16	2.59
	$Q_2$	86.59	333.44	83.36	81.87	105.77	4.72
	$Q_3$	86.37	321.5	80.38	78.07	110.64	8.30
	$Q_4$	63.86	303.03	75.76	74.65	85.55	-10.79
2016	$Q_1$	66.21	294.13	73.53	72.78	90.97	-6.57
	$Q_2$	77.69	288.11	72.03	76.44	101.64	1.25
	$Q_3$	80.35	323.38	80.85	86.70	92.67	-6.35
	$Q_4$	99.13	370.23	92.56	98.51	100.63	0.62
2017	$Q_1$	113.06	417.86	104.47	110.82	102.02	2.24
	$Q_2$	125.32	468.73	117.18	112.46	111.43	12.86
	$Q_3$	131.22	430.97	107.74			
	$Q_4$	61.37					

**Table 5:** Computations of Seasonal Indices (S.I)

Years	$Q_1$	$Q_2$	$Q_3$	$Q_4$
2001	-	-	122.97	81.13
2002	86.85	98.97	102.05	105.14
2003	84.72	108.85	110.07	96.05
2004	98.38	101.40	97.17	96.07
2005	101.86	113.91	111.01	79.73
2006	89.64	103.61	101.55	94.71
2007	102.50	110.62	105.43	80.71
2008	103.61	110.81	107.75	84.30
2009	94.10	105.02	111.14	91.00
2010	97.80	104.44	106.31	88.54
2011	92.29	103.36	101.45	93.11
2012	102.40	103.18	104.58	91.99
2013	97.19	114.85	106.09	85.94
2014	93.64	100.36	104.02	96.55
2015	103.16	105.77	110.64	85.55
2016	90.97	101.64	92.67	100.63
2017	102.02	111.43	-	-
Total	1541.13	1698.22	1694.9	1451.15
Average (P.S.I)	96.32	106.14	105.93	90.69
Adjusted S.I	96.5415	106.3841	106.1736	90.8986

**Table 6:** Computations of Seasonal Indices (S.I) for Trend Eliminated Values

Years	$Q_1$	$Q_2$	$Q_3$	$Q_4$
2001	-	-	9.51	-7.46
2002	-5.00	-0.41	0.90	2.51
2003	-8.45	5.32	6.44	-2.63
2004	-1.08	0.94	-1.96	-2.87
2005	1.42	10.47	7.65	-12.76
2006	-5.99	2.07	0.95	-3.48
2007	1.73	7.32	3.65	-12.72
2008	2.32	6.80	4.66	-8.85
2009	-3.17	2.65	5.82	-4.59
2010	-1.07	2.05	2.79	-4.91
2011	-3.29	1.49	0.69	-3.59
2012	1.35	1.91	2.88	-5.31
2013	-1.95	10.37	4.17	-9.30
2014	-4.14	0.24	2.95	-2.71
2015	2.59	4.72	8.30	-10.79
2016	-6.57	1.25	-6.35	0.62
2017	2.24	12.86	-	-
Total	-29.06	70.05	53.05	-88.84
Average (P.S.I)	-1.82	4.37	3.31	-5.55
Adjusted S.I	-1.8975	4.2925	3.2325	-5.6275

**Table 7:** Ratio to Moving Average Method for GWLs in Zone-III

Years	Quarters	GWLs ( $U_t$ )	4-Quarterly Moving Totals	4-Quarterly Moving Averages	Centered Averages ( $T_t$ ) or Moving Average	$\frac{U_t}{T_t} \times 100$	Trend Eliminated Values ( $U_t - T_t$ )
2001	$Q_1$	31.92					
	$Q_2$	35.19					
	$Q_3$	38.55	122.31	30.58	29.20	132.02	9.35

	<b>Q<sub>4</sub></b>	16.65	111.29	27.82	26.69	62.38	-10.04
2002	<b>Q<sub>1</sub></b>	20.9	102.23	25.56	24.60	84.96	-3.70
	<b>Q<sub>2</sub></b>	26.13	94.57	23.64	25.50	102.47	0.63
	<b>Q<sub>3</sub></b>	30.89	109.44	27.36	30.21	102.24	0.68
	<b>Q<sub>4</sub></b>	31.52	132.27	33.07	35.23	89.47	-3.71
2003	<b>Q<sub>1</sub></b>	43.73	149.58	37.40	39.62	110.39	4.12
	<b>Q<sub>2</sub></b>	43.44	167.34	41.84	42.67	101.81	0.77
	<b>Q<sub>3</sub></b>	48.65	174	43.50	43.53	111.77	5.12
	<b>Q<sub>4</sub></b>	38.18	174.23	43.56	43.91	86.95	-5.73
2004	<b>Q<sub>1</sub></b>	43.96	177.05	44.26	44.27	99.29	-0.31
	<b>Q<sub>2</sub></b>	46.26	177.13	44.28	45.57	101.51	0.69
	<b>Q<sub>3</sub></b>	48.73	187.46	46.87	48.22	101.06	0.51
	<b>Q<sub>4</sub></b>	48.51	198.3	49.58	51.47	94.25	-2.96
2005	<b>Q<sub>1</sub></b>	54.8	213.44	53.36	54.15	101.21	0.65
	<b>Q<sub>2</sub></b>	61.4	219.74	54.94	51.86	118.40	9.54
	<b>Q<sub>3</sub></b>	55.03	195.13	48.78	45.20	121.75	9.83
	<b>Q<sub>4</sub></b>	23.9	166.45	41.61	37.93	63.00	-14.03
2006	<b>Q<sub>1</sub></b>	26.12	137.02	34.26	31.91	81.85	-5.79
	<b>Q<sub>2</sub></b>	31.97	118.27	29.57	31.16	102.60	0.81
	<b>Q<sub>3</sub></b>	36.28	131.02	32.76	34.98	103.72	1.30
	<b>Q<sub>4</sub></b>	36.65	148.8	37.20	39.32	93.22	-2.67
2007	<b>Q<sub>1</sub></b>	43.9	165.73	41.43	42.32	103.72	1.58
	<b>Q<sub>2</sub></b>	48.9	172.86	43.22	42.96	113.84	5.95
	<b>Q<sub>3</sub></b>	43.41	170.78	42.70	40.69	106.69	2.72
	<b>Q<sub>4</sub></b>	34.57	154.72	38.68	36.40	94.96	-1.83
2008	<b>Q<sub>1</sub></b>	27.84	136.51	34.13	32.63	85.32	-4.79
	<b>Q<sub>2</sub></b>	30.69	124.52	31.13	29.49	104.07	1.20
	<b>Q<sub>3</sub></b>	31.42	111.4	27.85	28.05	112.01	3.37
	<b>Q<sub>4</sub></b>	21.45	113	28.25	28.68	74.80	-7.23
2009	<b>Q<sub>1</sub></b>	29.44	116.41	29.10	29.89	98.49	-0.45
	<b>Q<sub>2</sub></b>	34.1	122.73	30.68	31.97	106.67	2.13
	<b>Q<sub>3</sub></b>	37.74	133.01	33.25	34.08	110.73	3.66
	<b>Q<sub>4</sub></b>	31.73	139.66	34.92	36.06	87.98	-4.33
2010	<b>Q<sub>1</sub></b>	36.09	148.85	37.21	37.45	96.37	-1.36
	<b>Q<sub>2</sub></b>	43.29	150.73	37.68	36.89	117.36	6.40
	<b>Q<sub>3</sub></b>	39.62	144.36	36.09	35.00	113.19	4.62
	<b>Q<sub>4</sub></b>	25.36	135.67	33.92	33.17	76.45	-7.81
2011	<b>Q<sub>1</sub></b>	27.4	129.69	32.42	32.25	84.95	-4.85
	<b>Q<sub>2</sub></b>	37.31	128.33	32.08	33.25	112.21	4.06
	<b>Q<sub>3</sub></b>	38.26	137.67	34.42	36.38	105.16	1.88
	<b>Q<sub>4</sub></b>	34.7	153.39	38.35	39.77	87.24	-5.07



2012	$Q_1$	43.12	164.8	41.20	42.93	100.43	0.19
	$Q_2$	48.72	178.67	44.67	46.53	104.71	2.19
	$Q_3$	52.13	193.57	48.39	50.09	104.07	2.04
	$Q_4$	49.6	207.16	51.79	54.83	90.46	-5.23
2013	$Q_1$	56.71	231.5	57.88	59.49	95.32	-2.78
	$Q_2$	73.06	244.43	61.11	59.19	123.43	13.87
	$Q_3$	65.06	229.1	57.28	55.33	117.59	9.73
	$Q_4$	34.27	213.52	53.38	50.63	67.69	-16.36
2014	$Q_1$	41.13	191.53	47.88	48.45	84.89	-7.32
	$Q_2$	51.07	196.07	49.02	54.15	94.31	-3.08
	$Q_3$	69.6	237.15	59.29	65.18	106.78	4.42
	$Q_4$	75.35	284.28	71.07	76.34	98.70	-0.99
2015	$Q_1$	88.26	326.44	81.61	83.73	105.41	4.53
	$Q_2$	93.23	343.42	85.86	82.51	112.99	10.72
	$Q_3$	86.58	316.65	79.16	72.40	119.59	14.19
	$Q_4$	48.58	262.51	65.63	59.15	82.14	-10.57
2016	$Q_1$	34.12	210.65	52.66	47.31	72.13	-13.19
	$Q_2$	41.37	167.8	41.95	44.00	94.03	-2.63
	$Q_3$	43.73	184.19	46.05	51.25	85.33	-7.52
	$Q_4$	64.97	225.78	56.45	62.43	104.08	2.55
2017	$Q_1$	75.71	273.62	68.41	73.75	102.66	1.96
	$Q_2$	89.21	316.37	79.09	75.09	118.81	14.12
	$Q_3$	86.48	284.32	71.08			
	$Q_4$	32.92					

Table 8: Computations of Seasonal Indices (S.I)

Years	$Q_1$	$Q_2$	$Q_3$	$Q_4$
2001	-	-	132.02	62.38
2002	84.96	102.47	102.24	89.47
2003	110.39	101.81	111.77	86.95
2004	99.29	101.51	101.06	94.25
2005	101.21	118.40	121.75	63.00
2006	81.85	102.60	103.72	93.22
2007	103.72	113.84	106.69	94.96
2008	85.32	104.07	112.01	74.80
2009	98.49	106.67	110.73	87.98
2010	96.37	117.36	113.19	76.45
2011	84.95	112.21	105.16	87.24
2012	100.43	104.71	104.07	90.46
2013	95.32	123.43	117.59	67.69
2014	84.89	94.31	106.78	98.70
2015	105.41	112.99	119.59	82.14
2016	72.13	94.03	85.33	104.08
2017	102.66	118.81	-	-
Total	1507.39	1729.22	1753.7	1353.77
Average (P.S.I)	94.211	108.07	109.60	84.61
Adjusted S.I	95.0495	109.0318	110.5754	85.3630

**Table 9:** Computations of Seasonal Indices (S.I) for Trend Eliminated Values

Years	$Q_1$	$Q_2$	$Q_3$	$Q_4$
2001	-	-	9.35	-10.04
2002	-3.70	0.63	0.68	-3.71
2003	4.12	0.77	5.12	-5.73
2004	-0.31	0.69	0.51	-2.96
2005	0.65	9.54	9.83	-14.03
2006	-5.79	0.81	1.30	-2.67
2007	1.58	5.95	2.72	-1.83
2008	-4.79	1.20	3.37	-7.23
2009	-0.45	2.13	3.66	-4.33
2010	-1.36	6.40	4.62	-7.81
2011	-4.85	4.06	1.88	-5.07
2012	0.19	2.19	2.04	-5.23
2013	-2.78	13.87	9.73	-16.36
2014	-7.32	-3.08	4.42	-0.99
2015	4.53	10.72	14.19	-10.57
2016	-13.19	-2.63	-7.52	2.55
2017	1.96	14.12	-	-
Total	-31.51	67.37	65.9	-96.01
Average (P.S.I)	-1.97	4.21	4.12	-6.00
Adjusted S.I	-2.06	4.12	4.03	-6.09

**Table 10:** Ratio to Moving Average Method for GWLs in Zone-IV

Years	Quarters	GWLs ( $U_t$ )	4-Quarterly Moving Totals	4-Quarterly Moving Averages	Centered Averages ( $T_t$ ) or Moving Average	$\frac{U_t}{T_t} \times 100$	Trend Eliminated Values ( $U_t - T_t$ )
2001	$Q_1$	29.5					
	$Q_2$	36.19					
	$Q_3$	38.97	131.25	32.81	32.45	120.08	6.52
	$Q_4$	26.59	128.37	32.09	31.47	84.48	-4.88
2002	$Q_1$	26.62	123.42	30.86	30.09	88.47	-3.47
	$Q_2$	31.24	117.3	29.33	30.18	103.50	1.06
	$Q_3$	32.85	124.17	31.04	32.42	101.32	0.43
	$Q_4$	33.46	135.21	33.80	35.34	94.69	-1.88
2003	$Q_1$	37.66	147.49	36.87	38.76	97.15	-1.10
	$Q_2$	43.52	162.62	40.66	42.46	102.49	1.06
	$Q_3$	47.98	177.09	44.27	45.92	104.50	2.06
	$Q_4$	47.93	190.23	47.56	48.62	98.59	-0.69
2004	$Q_1$	50.8	198.71	49.68	50.20	101.20	0.60
	$Q_2$	52	202.86	50.72	51.59	100.80	0.41
	$Q_3$	52.13	209.85	52.46	53.65	97.17	-1.52
	$Q_4$	54.92	219.35	54.84	56.32	97.51	-1.40
2005	$Q_1$	60.3	231.21	57.80	58.02	103.93	2.28
	$Q_2$	63.86	232.95	58.24	55.79	114.46	8.07
	$Q_3$	53.87	213.4	53.35	50.68	106.29	3.19
	$Q_4$	35.37	192.07	48.02	45.46	77.80	-10.09

2006	$Q_1$	38.97	171.64	42.91	42.07	92.63	-3.10
	$Q_2$	43.43	164.91	41.23	42.41	102.40	1.02
	$Q_3$	47.14	174.4	43.60	44.51	105.90	2.63
	$Q_4$	44.86	181.71	45.43	46.29	96.90	-1.43
2007	$Q_1$	46.28	188.64	47.16	47.12	98.22	-0.84
	$Q_2$	50.36	188.32	47.08	46.04	109.38	4.32
	$Q_3$	46.82	180.01	45.00	43.69	107.15	3.13
	$Q_4$	36.55	169.54	42.39	40.69	89.82	-4.14
2008	$Q_1$	35.81	156	39.00	37.27	96.09	-1.46
	$Q_2$	36.82	142.14	35.54	34.08	108.03	2.74
	$Q_3$	32.96	130.53	32.63	31.75	103.80	1.21
	$Q_4$	24.94	123.5	30.88	30.36	82.16	-5.42
2009	$Q_1$	28.78	119.34	29.84	29.83	96.49	-1.05
	$Q_2$	32.66	119.27	29.82	29.27	111.58	3.39
	$Q_3$	32.89	114.9	28.73	28.32	116.13	4.57
	$Q_4$	20.57	111.67	27.92	27.57	74.61	-7.00
2010	$Q_1$	25.55	108.89	27.22	26.50	96.42	-0.95
	$Q_2$	29.88	103.09	25.77	25.75	116.03	4.13
	$Q_3$	27.09	102.92	25.73	25.24	107.31	1.85
	$Q_4$	20.4	99.03	24.76	24.21	84.28	-3.81
2011	$Q_1$	21.66	94.61	23.65	23.89	90.65	-2.23
	$Q_2$	25.46	96.54	24.14	25.49	99.89	-0.03
	$Q_3$	29.02	107.36	26.84	28.95	100.25	0.07
	$Q_4$	31.22	124.22	31.06	33.16	94.16	-1.94
2012	$Q_1$	38.52	141.02	35.26	37.14	103.72	1.38
	$Q_2$	42.26	156.08	39.02	40.16	105.24	2.11
	$Q_3$	44.08	165.16	41.29	42.36	104.07	1.72
	$Q_4$	40.3	173.68	43.42	44.90	89.77	-4.60
2013	$Q_1$	47.04	185.48	46.37	47.64	98.74	-0.60
	$Q_2$	54.06	195.63	48.91	49.91	108.32	4.15
	$Q_3$	54.23	203.63	50.91	51.74	104.80	2.49
	$Q_4$	48.3	210.32	52.58	53.22	90.75	-4.92
2014	$Q_1$	53.73	215.47	53.87	54.34	98.88	-0.61
	$Q_2$	59.21	219.23	54.81	55.77	106.17	3.44
	$Q_3$	57.99	226.91	56.73	57.48	100.88	0.51
	$Q_4$	55.98	232.96	58.24	58.71	95.36	-2.73
2015	$Q_1$	59.78	236.69	59.17	59.74	100.08	0.05
	$Q_2$	62.94	241.19	60.30	59.01	106.66	3.93
	$Q_3$	62.49	230.88	57.72	56.62	110.36	5.87
	$Q_4$	45.67	222.1	55.53	54.67	83.53	-9.00
2016	$Q_1$	51	215.28	53.82	53.61	95.14	-2.61

	<b>Q<sub>2</sub></b>	56.12	213.58	53.40	55.94	100.33	0.18
	<b>Q<sub>3</sub></b>	60.79	233.92	58.48	60.91	99.80	-0.12
	<b>Q<sub>4</sub></b>	66.01	253.37	63.34	66.08	99.89	-0.07
2017	<b>Q<sub>1</sub></b>	70.45	275.3	68.83	71.46	98.58	-1.01
	<b>Q<sub>2</sub></b>	78.05	296.41	74.10	71.14	109.71	6.91
	<b>Q<sub>3</sub></b>	81.9	272.71	68.18			
	<b>Q<sub>4</sub></b>	42.31					

**Table 11:** Computations of Seasonal Indices (S.I)

Years	<b>Q<sub>1</sub></b>	<b>Q<sub>2</sub></b>	<b>Q<sub>3</sub></b>	<b>Q<sub>4</sub></b>
2001	-	-	120.08	84.48
2002	88.47	103.50	101.32	94.69
2003	97.15	102.49	104.50	98.59
2004	101.20	100.80	97.17	97.51
2005	103.93	114.46	106.29	77.80
2006	92.63	102.40	105.90	96.90
2007	98.22	109.38	107.15	89.82
2008	96.09	108.03	103.80	82.16
2009	96.49	111.58	116.13	74.61
2010	96.42	116.03	107.31	84.28
2011	90.65	99.89	100.25	94.16
2012	103.72	105.24	104.07	89.77
2013	98.74	108.32	104.80	90.75
2014	98.88	106.17	100.88	95.36
2015	100.08	106.66	110.36	83.53
2016	95.14	100.33	99.80	99.89
2017	98.58	109.71	-	-
Total	1556.39	1704.99	1689.81	1434.3
Average (P.S.I)	97.27	106.56	105.61	89.64
Adjusted S.I	97.4937	106.8051	105.8529	89.8462

**Table 12:** Computations of Seasonal Indices (S.I) for Trend Eliminated Values

Years	<b>Q<sub>1</sub></b>	<b>Q<sub>2</sub></b>	<b>Q<sub>3</sub></b>	<b>Q<sub>4</sub></b>
2001	-	-	6.52	-4.88
2002	-3.47	1.06	0.43	-1.88
2003	-1.10	1.06	2.06	-0.69
2004	0.60	0.41	-1.52	-1.40
2005	2.28	8.07	3.19	-10.09
2006	-3.10	1.02	2.63	-1.43
2007	-0.84	4.32	3.13	-4.14
2008	-1.46	2.74	1.21	-5.42
2009	-1.05	3.39	4.57	-7.00
2010	-0.95	4.13	1.85	-3.81
2011	-2.23	-0.03	0.07	-1.94
2012	1.38	2.11	1.72	-4.60
2013	-0.60	4.15	2.49	-4.92
2014	-0.61	3.44	0.51	-2.73
2015	0.05	3.93	5.87	-9.00
2016	-2.61	0.18	-0.12	-0.07
2017	-1.01	6.91	-	-
Total	-14.72	46.89	34.61	-64
Average (P.S.I)	-0.92	2.93	2.16	-4
Adjusted S.I	-0.9625	2.8875	2.1175	-4.0425

**Table 13:** Ratio to Moving Average Method for GWLs in Zone-V

Years	Quarters	GWLs ( $U_t$ )	4-Quarterly Moving Totals	4-Quarterly Moving Averages	Centered Averages ( $T_t$ ) or Moving Average	$\frac{U_t}{T_t} \times 100$	Trend Eliminated Values ( $U_t - T_t$ )
2001	$Q_1$	34.8					
	$Q_2$	39.01					
	$Q_3$	44.73	134.65	33.66	32.08	139.43	12.65
	$Q_4$	16.11	121.99	30.50	28.79	55.96	-12.68
2002	$Q_1$	22.14	108.33	27.08	25.16	88.01	-3.02
	$Q_2$	25.35	92.93	23.23	25.12	100.92	0.23
	$Q_3$	29.33	108.02	27.01	29.63	98.99	-0.30
	$Q_4$	31.2	129.01	32.25	34.56	90.27	-3.36
2003	$Q_1$	43.13	147.49	36.87	39.29	109.78	3.84
	$Q_2$	43.83	166.81	41.70	43.35	101.10	0.48
	$Q_3$	48.65	180.02	45.01	45.62	106.65	3.04
	$Q_4$	44.41	184.9	46.23	47.12	94.25	-2.71
2004	$Q_1$	48.01	192.07	48.02	48.20	99.60	-0.19
	$Q_2$	51	193.54	48.39	49.41	103.21	1.59
	$Q_3$	50.12	201.77	50.44	51.67	97.01	-1.55
	$Q_4$	52.64	211.56	52.89	54.68	96.28	-2.04
2005	$Q_1$	57.8	225.84	56.46	57.25	100.96	0.55
	$Q_2$	65.28	232.18	58.05	56.19	116.17	9.09
	$Q_3$	56.46	217.37	54.34	52.64	107.27	3.83
	$Q_4$	37.83	203.71	50.93	48.73	77.63	-10.90
2006	$Q_1$	44.14	186.13	46.53	45.57	96.86	-1.43
	$Q_2$	47.7	178.42	44.61	47.00	101.49	0.70
	$Q_3$	48.75	197.57	49.39	50.61	96.32	-1.86
	$Q_4$	56.98	207.33	51.83	53.43	106.65	3.55
2007	$Q_1$	53.9	220.1	55.03	55.51	97.10	-1.61
	$Q_2$	60.47	223.96	55.99	53.54	112.95	6.94
	$Q_3$	52.61	204.32	51.08	47.65	110.41	4.96
	$Q_4$	37.34	176.89	44.22	40.70	91.74	-3.36
2008	$Q_1$	26.47	148.73	37.18	34.35	77.06	-7.88
	$Q_2$	32.31	126.08	31.52	29.39	109.94	2.92
	$Q_3$	29.96	109.04	27.26	27.00	110.98	2.97
	$Q_4$	20.3	106.92	26.73	26.16	77.59	-5.86
2009	$Q_1$	24.35	102.39	25.60	26.30	92.60	-1.95
	$Q_2$	27.78	107.98	27.00	28.87	96.24	-1.09
	$Q_3$	35.55	122.94	30.74	32.12	110.69	3.43
	$Q_4$	35.26	134	33.50	34.92	100.98	0.34
2010	$Q_1$	35.41	145.35	36.34	36.31	97.53	-0.89
	$Q_2$	39.13	145.09	36.27	35.82	109.23	3.31

	$Q_3$	35.29	141.49	35.37	35.23	100.17	0.06
	$Q_4$	31.66	140.34	35.09	35.08	90.24	-3.42
2011	$Q_1$	34.26	140.32	35.08	35.74	95.85	-1.48
	$Q_2$	39.11	145.63	36.41	37.42	104.51	1.69
	$Q_3$	40.6	153.76	38.44	38.59	105.22	2.02
	$Q_4$	39.79	154.92	38.73	38.83	102.48	0.96
2012	$Q_1$	35.42	155.7	38.93	39.13	90.52	-3.71
	$Q_2$	39.89	157.32	39.33	39.46	101.09	0.43
	$Q_3$	42.22	158.35	39.59	41.06	102.82	1.16
	$Q_4$	40.82	170.14	42.54	43.61	93.60	-2.79
2013	$Q_1$	47.21	178.75	44.69	44.66	105.71	2.55
	$Q_2$	48.5	178.53	44.63	43.66	111.08	4.84
	$Q_3$	42	170.77	42.69	41.43	101.37	0.57
	$Q_4$	33.06	160.7	40.18	39.42	83.86	-6.36
2014	$Q_1$	37.14	154.68	38.67	39.76	93.41	-2.62
	$Q_2$	42.48	163.41	40.85	43.49	97.68	-1.01
	$Q_3$	50.73	184.49	46.12	48.68	104.22	2.05
	$Q_4$	54.14	204.92	51.23	52.95	102.25	1.19
2015	$Q_1$	57.57	218.67	54.67	55.08	104.53	2.49
	$Q_2$	56.23	221.95	55.49	54.26	103.64	1.98
	$Q_3$	54.01	212.09	53.02	51.46	104.96	2.55
	$Q_4$	44.28	199.58	49.90	49.16	90.08	-4.88
2016	$Q_1$	45.06	193.69	48.42	47.22	95.42	-2.16
	$Q_2$	50.34	184.1	46.03	47.22	106.62	3.12
	$Q_3$	44.42	193.63	48.41	50.00	88.85	-5.58
	$Q_4$	53.81	206.33	51.58	53.10	101.34	0.71
2017	$Q_1$	57.76	218.47	54.62	57.13	101.10	0.63
	$Q_2$	62.48	238.56	59.64	55.59	112.40	6.90
	$Q_3$	64.51	206.12	51.53			
	$Q_4$	21.37					

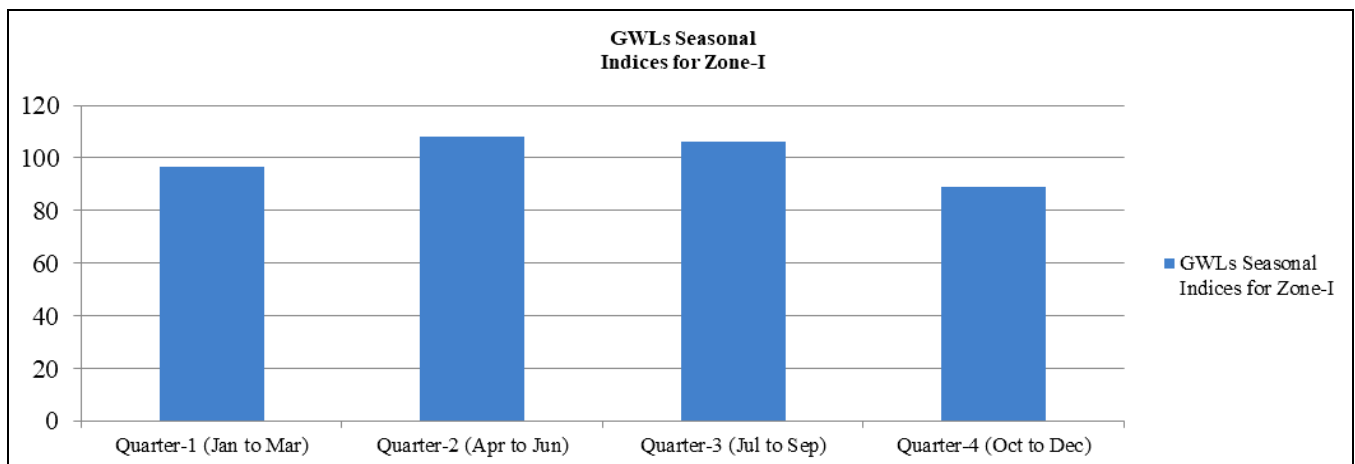
Table 14: Computations of Seasonal Indices (S.I)

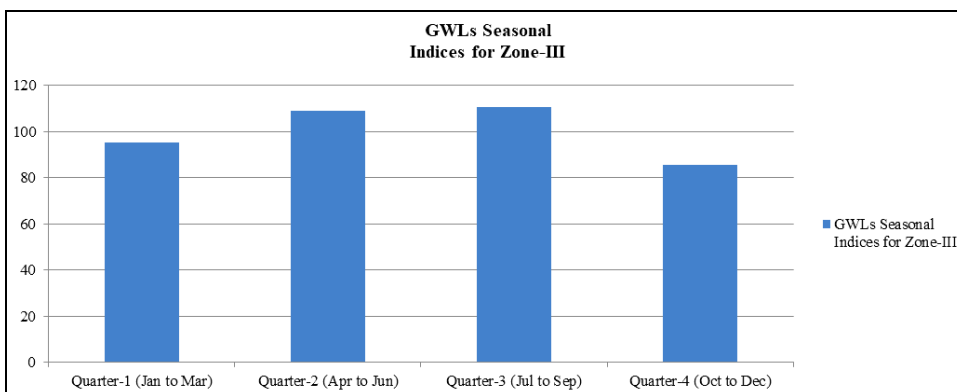
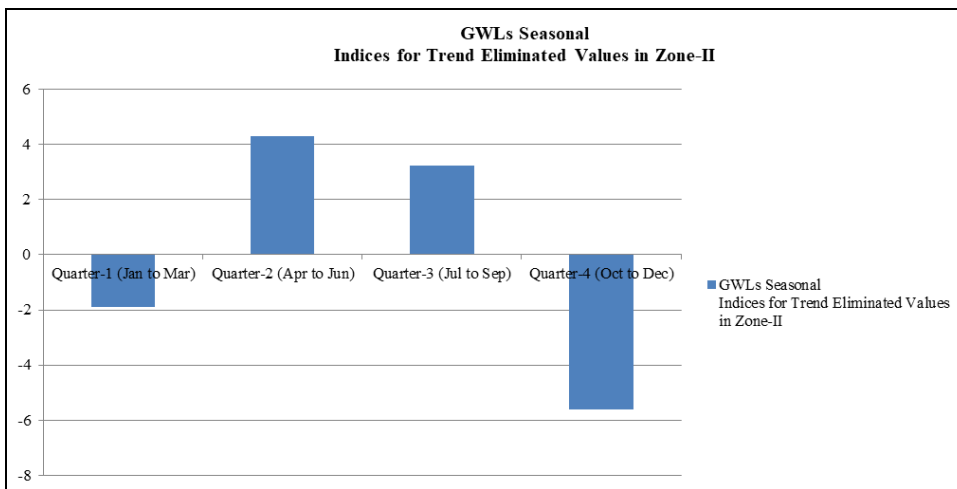
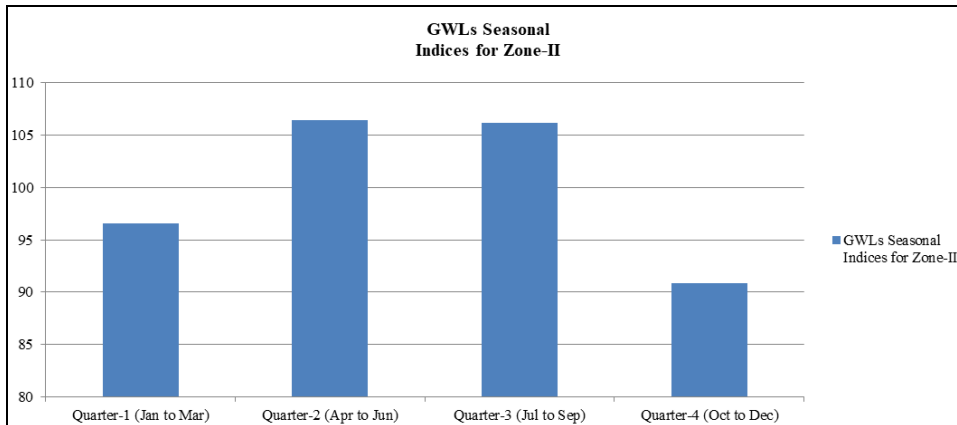
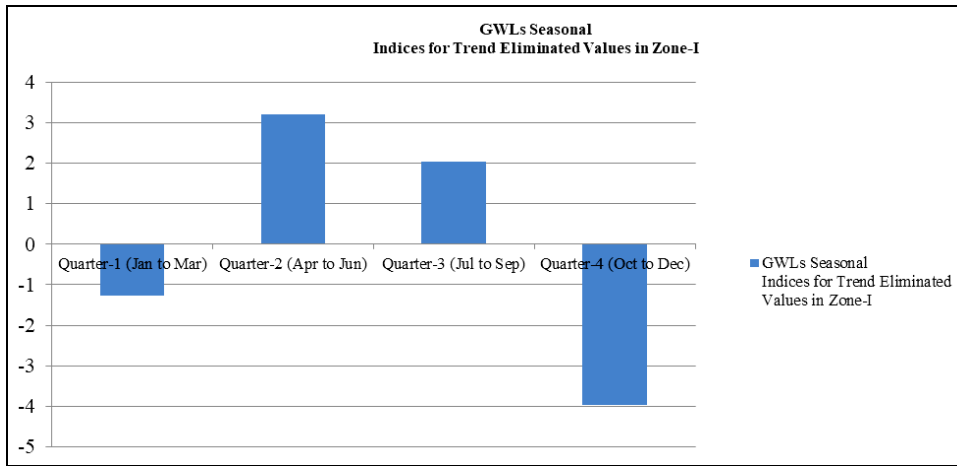
Years	$Q_1$	$Q_2$	$Q_3$	$Q_4$
2001	-	-	139.43	55.96
2002	88.01	100.92	98.99	90.27
2003	109.78	101.10	106.65	94.25
2004	99.60	103.21	97.01	96.28
2005	100.96	116.17	107.27	77.63
2006	96.86	101.49	96.32	106.65
2007	97.10	112.95	110.41	91.74
2008	77.06	109.94	110.98	77.59
2009	92.60	96.24	110.69	100.98
2010	97.53	109.23	100.17	90.24
2011	95.85	104.51	105.22	102.48

2012	90.52	101.09	102.80	93.60
2013	105.71	111.08	101.37	83.86
2014	93.41	97.68	104.22	102.25
2015	104.53	103.64	104.96	90.08
2016	95.42	106.62	88.85	101.34
2017	101.10	112.40	-	-
Total	1546.04	1688.27	1685.34	1455.2
Average (P.S.I)	96.63	105.52	105.33	90.95
Adjusted S.I	97.0069	105.9315	105.7408	91.3047

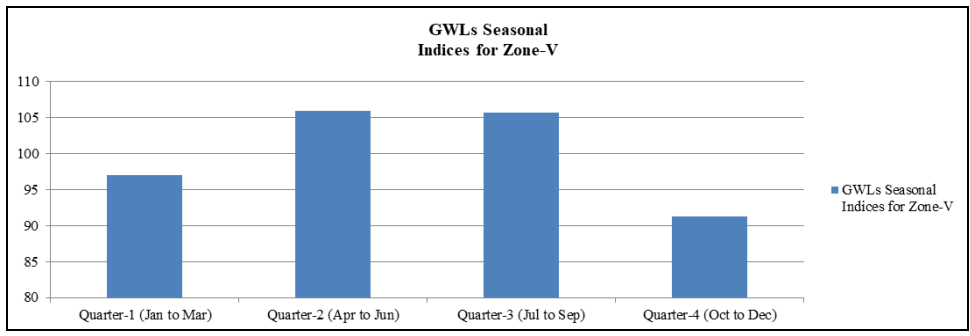
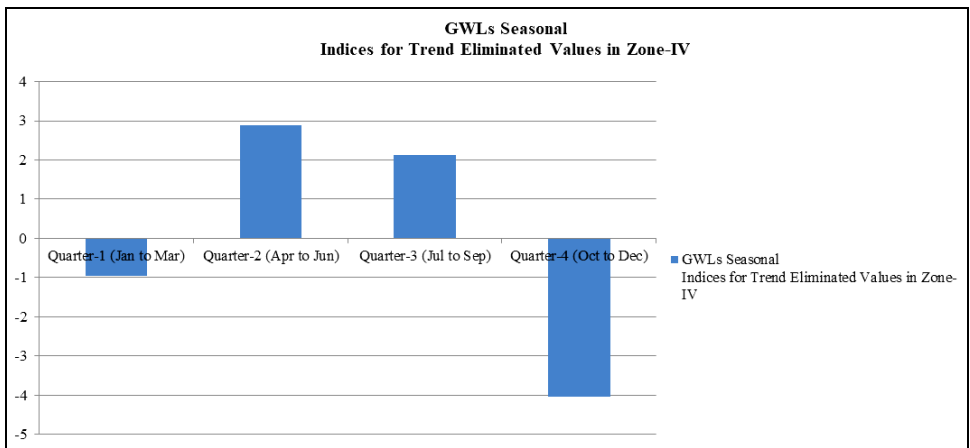
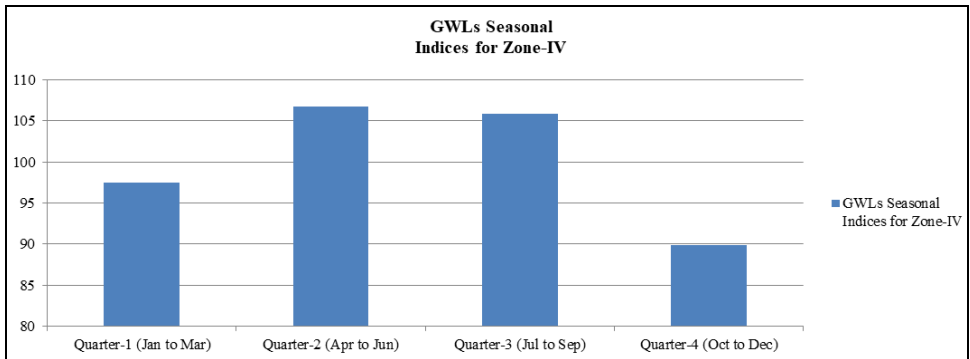
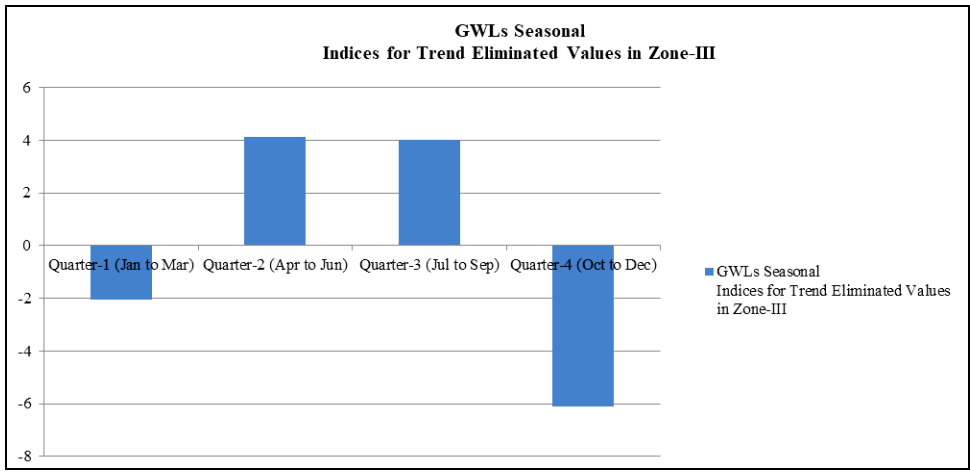
**Table 15:** Computations of Seasonal Indices (S.I) for Trend Eliminated Values

Years	$Q_1$	$Q_2$	$Q_3$	$Q_4$
2001	-	-	12.65	-12.68
2002	3.02	0.23	-0.30	-3.36
2003	3.84	0.48	3.04	-2.71
2004	-0.19	1.59	-1.55	-2.04
2005	0.55	9.09	3.83	-10.90
2006	-1.43	0.70	-1.86	3.55
2007	-1.61	6.94	4.96	-3.36
2008	-7.88	2.92	2.97	-5.86
2009	-1.95	-1.09	3.43	0.34
2010	-0.89	3.31	0.06	-3.42
2011	-1.48	1.69	2.02	0.96
2012	-3.71	0.43	1.16	-2.79
2013	2.55	4.84	0.57	-6.36
2014	-2.62	-1.01	2.05	1.19
2015	2.49	1.98	2.55	-4.88
2016	-2.16	3.12	-5.58	0.71
2017	0.63	6.90	-	-
Total	-10.84	42.12	30	-51.61
Average (P.S.I)	-0.68	2.63	1.88	-3.23
Adjusted S.I	-0.8300	2.4800	1.7300	-3.3800









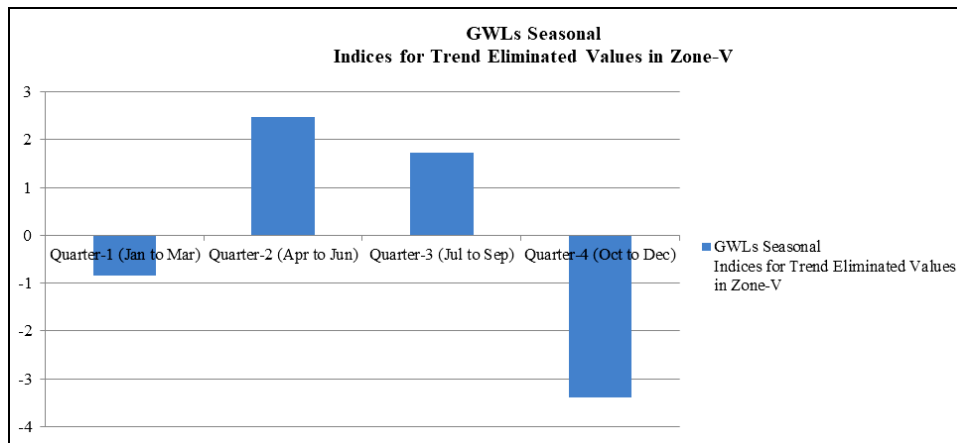


Fig 1: GWLs Seasonal Indices Graphs for Zone-I to Zone-V

## Conclusion

By comparing critically Quarterly Seasonal Indices for GWLs along with their corresponding graphs after eliminating trend effects given in Figure: 3.1 the following conclusions can be drawn:

In All Revenue Divisions (RD) or Zones in Anantapuramu District, Seasonal Indices for Quarters clearly reveals that it is high GWLs in Quarter-2 (April to June) and Quarter-3 (July to September) and Low in Quarter-1 (January to March) and Quarter-4 (October to December). Same effect is continued after eliminating the Trend Values

This is because of the fact that in every year especially hot weather season (summer) the Ground Water Levels is very high. Here high means the water level is going deeper and deeper. In general we can observe that as the Rainfall is increasing the depth of the Ground Water Level will be decreasing. It can observe through these graphs, in all the Zones under consideration the Ground Water Levels from 2001 January to 2017 November which is resulted in increasing the depth of the Ground Water Levels.

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