Stream Model

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Outline

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- Description of plugin
- Discussion on results
- Pending work

Introduction

Currently farm water balance model produces runoff at the village level. There is need to interlink the runoff output of one village with the other and understand the stream flow process.

Objective

- To interlink the farm runoff with the streams.
- To interlink the flows of the upstream village with the downstream village.
- To understand the losses occurring through the stream network

In this presentation we will discuss about the new plugin developed in the QGIS to simulate the stream flow process, extraction of stream features and scope of the improvement. Results obtained using plugin for the Gondala cluster.

Description about the plugin

Input

- Plugin uses DEM file and runoff file (from farm water balance model) as input.
- Stream network for selecting input point for watershed delineation.
- User provides an input coordinate as outlet point. For this watershed gets delineated.

Output 1

- Within this watershed plugin generates contributing areas for each stream.
- Using dem file and different modules it computes the segment id’s, stream order, node points, stream linkages, length, depth etc.
- Plugin uses peak runoff data and manning's equation for calculation of width for different streams.

Output 2

- This is then used water routing method for calculation of stream flows and losses across the stream network.

Modules used in the plugin

1 grass: r.watershed - module is used to generate the stream segment.

2 saga: channelnetworkanddrainagebasins - this module is used to compute the stream network with required segment id, node points, order, stream connections.

3 Depth calculation - An algorithm is written which computes the depth of stream network using the pixels on both sides if the stream pixel.

4 r.water.outlet - is used to compute the watersheds for each segment.

5 Width calculation - Manning’s flow equation is used to calculate the width of stream segments. It uses the peak runoff, depth and width computed using the above algorithms.

Basin delineation and differential watershed generation

a) Input DEM Raster layer

b) Watershed basin is generated for the given point

c) Stream network is generated from clipped Raster layer

a) Watershed basin for order 2 stream segment

b) Watershed basin for (1st source) order1 stream segment

c) Watershed basin for (2nd source) order1 stream segment

d) Subtracting basin area of source streams from order 2 stream network

Attribute table with different stream features

	SEGMENT_ID	NODE_A	NODE_B	BASIN	ORDER	ORDER_CELL	LENGTH	DEPTH	BASIN AREA	SLOPE	B_WIDTH	T_WIDTH	SOURCES	Q
1	1	3	2	2	1	6	405.6980515300	1.00000	387187.50000	0.01232	1.14420	1.14420	NULL	1.29493
2	2	4	1	1	3	8	631.5863991800	1.11111	209062.50000	0.00317	16.08731	16.08731	4, 5	19.79754
3	3	5	7	1	1	6	530.6980515300	1.31579	245000.00000	0.01696	0.60764	0.60764	NULL	0.81939
4	4	6	4	1	2	7	316.4213562400	1.25000	89062.50000	0.00948	5.80522	5.80522	6, 7	12.91530
5	5	7	4	1	2	7	887.6524163600	1.13333	460468.75000	0.01239	3.21680	3.21680	3, 8	6.18304
6	6	8	6	1	1	6	468.1980515300	1.29412	267187.50000	0.02349	0.58536	0.58536	NULL	0.89359
7	7	9	6	1	2	7	571.2310601200	1.42105	299218.75000	0.0105	4.43099	4.43099	9, 13	11.72385
8	8	10	7	1	1	6	1269.6067812000	1.27451	1143281.25000	0.00945	2.19435	2.19435	NULL	3.82364
9	9	11	9	1	2	7	279.8097038900	1.20000	134218.75000	0.00357	4.53081	4.53081	10, 11	5.52931
10	10	12	11	1	1	6	319.4543648300	1.83333	549218.75000	0.01878	0.77919	0.77919	NULL	1.83683
11	11	13	11	1	2	7	929.4417382400	1.80952	326093.75000	0.01076	1.37492	1.37492	12, 14	3.24359
12	12	14	13	1	1	6	191.4213562400	1.00000	350625.00000	0.00522	1.44695	1.44695	NULL	1.17265
13	13	15	9	1	1	6	1677.4494937000	1.18919	1552968.75000	0.00835	3.10997	3.10997	NULL	5.19382
14	14	16	13	1	1	6	277.6650429400	1.00000	293125.00000	0.0036	1.45412	1.45412	NULL	0.98034

Segment Id - unique segment id
Noda_A - starting point of a stream
Node_B - end point of a stream
Order - strahler order of stream
Length - lenght of stream segment (m)
Slope of stream segment

Basin area - contributing area to stream segment (m2)
Slope - slope of stream segment
B_Width - Bottom Width (m)
T_Width - Top Width (m)
Sources - Contributing streams to given stream
Q- Peak Discharge rate (m3/h)

Stream flow routine after stream feature extraction

1. Initially, it is assumed that the side slope (run to rise ratio) is 2:1 or Zch =2 for stream segment.
2. For given watershed, at the beginning of first time step amount of water stored in channel is set equal to the amount of runoff generated for that differential watershed + existing storage if any which is generally zero.
3. If there is no inflow from the upstream, Volume in will be set equal to zero.
4. This water is routed into the channel and depth of water in the channel is calculated.
5. Once depth of water level is known cross section area at water level, wetted perimeter and hydraulic radius are calculated.
6. Using manning's equation flow/discharge in the channel is computed.
7. Volume out, at the end of time step will computed using the storage coefficient.

Cont.

8 Various losses are computed and subtracted from the existing storage to get the net storage in the channel at the end of time step.

9 Net storage will act as initial storage for the next time step and runoff generated from the watershed for the next time step will be added in to this to compute the Total storage for next time step.

10 This total storage will be used as volume to compute the new area of depth, hydraulic radius, wetted perimeter velocity etc.

11. Volume out for the first time step of one segment will act as Volume in, for the next stream segment in line.

Output CSV with result for stream network

stream_id	time_step	runoff_	runoff_volume	total_volume_stored	volume_in	discharge	transmission_loss	bankin	return_flow_from_bank	evaporation_loss	total_loss	volume_after_loss	volume_o	volur
1	0												0	
1	24	0.03	18.83	18.83	0.00	0.00	18.83	9.41	2.44	0.08	18.91	0.00	0.00	
1	25	0.06	45.35	47.79	0.00	0.02	12.30	6.15	1.59	0.06	12.36	35.43	29.80	
1	28	0.02	17.22	17.34	0.00	0.00	17.34	8.67	2.25	0.08	17.42	0.00	0.00	
1	74	0.09	65.71	65.71	0.00	0.03	10.79	5.39	1.40	0.05	10.84	54.87	51.01	
1	75	0.18	122.91	128.17	0.00	0.09	8.77	4.39	1.14	0.04	8.81	119.36	119.36	
1	102	0.07	45.70	45.70	0.00	0.02	12.55	6.27	1.63	0.06	12.61	33.09	27.41	
1	103	0.06	44.16	51.47	0.00	0.02	11.91	5.96	1.54	0.06	11.97	39.50	34.04	
1	122	0.08	55.23	55.23	0.00	0.02	11.56	5.78	1.50	0.06	11.62	43.61	38.44	
1	149	0.06	42.31	42.31	0.00	0.02	13.00	6.50	1.68	0.06	13.06	29.25	23.59	
1	150	0.05	37.89	45.23	0.00	0.02	12.61	6.30	1.63	0.06	12.67	32.56	26.87	
1	178	0.03	21.14	21.14	0.00	0.01	18.51	9.26	2.40	0.08	18.60	2.54	1.57	
1	179	0.07	51.30	54.68	0.00	0.02	11.61	5.81	1.50	0.06	11.67	43.01	37.79	
1	194	0.10	70.40	70.40	0.00	0.04	10.51	5.26	1.36	0.05	10.56	59.84	56.76	
1	195	0.12	83.34	87.79	0.00	0.05	9.75	4.87	1.26	0.05	9.79	78.00	78.00	
1	196	0.06	42.44	43.70	0.00	0.02	12.81	6.40	1.66	0.06	12.87	30.83	25.15	
1	197	0.02	11.03	18.38	0.00	0.00	18.38	9.19	2.38	0.08	18.46	0.00	0.00	
1	216	0.02	12.79	12.79	0.00	0.00	12.79	6.40	1.66	0.08	12.87	0.00	0.00	
1	217	0.07	47.86	49.52	0.00	0.02	12.11	6.06	1.57	0.06	12.17	37.35	31.78	
1	481	0.16	110.88	110.88	0.00	0.07	9.10	4.55	1.18	0.04	9.14	101.74	101.74	
1	482	0.08	56.84	58.02	0.00	0.03	11.33	5.67	1.47	0.05	11.39	46.64	41.75	
1	483	0.06	40.12	46.48	0.00	0.02	12.45	6.23	1.61	0.06	12.51	33.97	28.30	

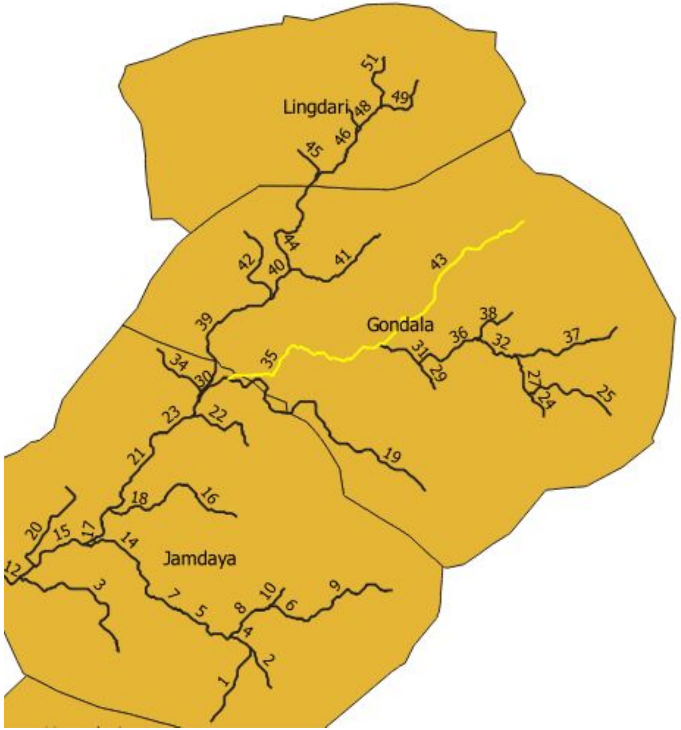
Stream Flow Data-1 | Sheet1

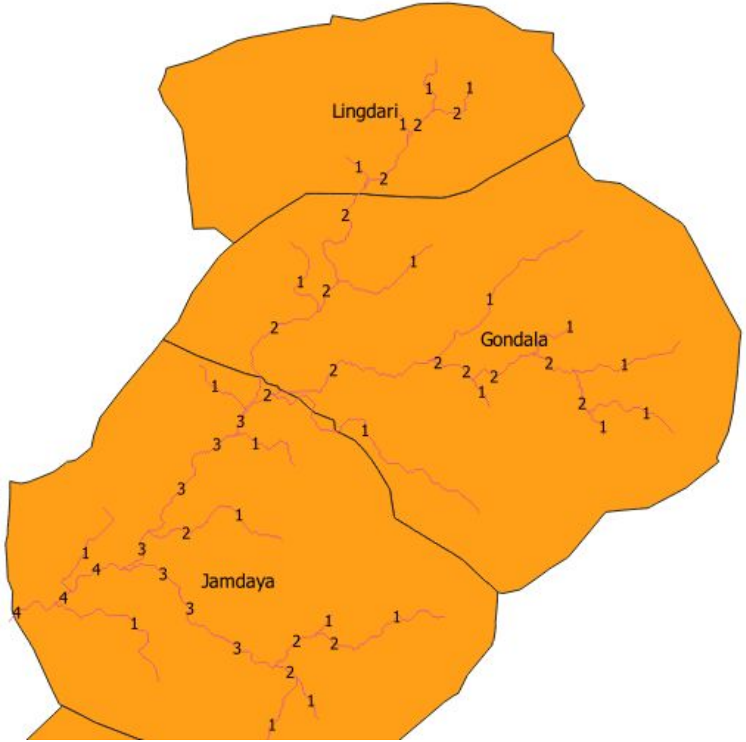
Result for Gondala Cluster

Palsar DEM of 12.5 meter resolution was used for calculating the depth of streams.

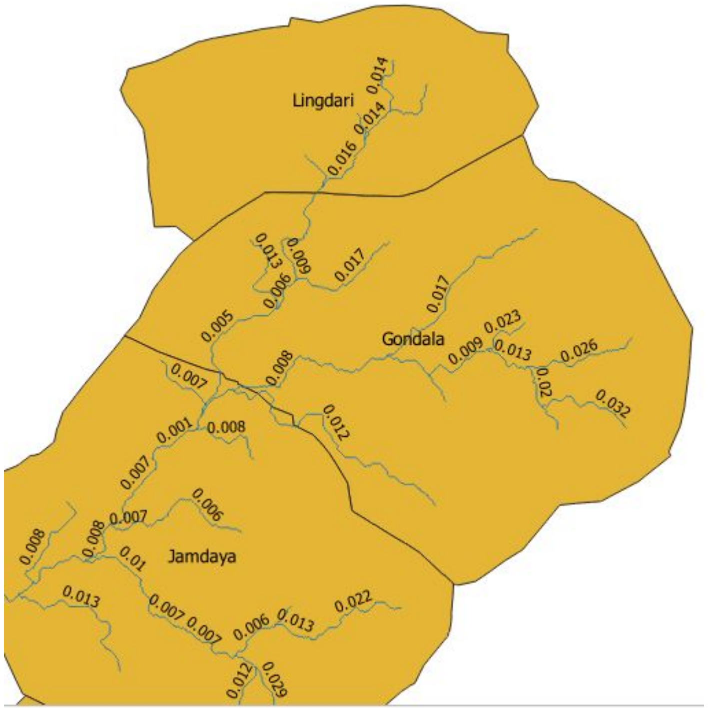
1. Two cases were made for depth calculation. One with 1 pixel (12.5m) both sides across the stream bed and second with 2 pixels both sides across the stream bed.
2. As the depth of the stream increased, width of the stream reduced.
3. As width is calculated using the peak runoff value, in case of 2019 peak runoff value is more so width calculated for streams is more. In case of 2018, peak runoff is less width calculated is less.
4. Transmission losses are more in year 2019 due to more width and more rainfall-runoff.

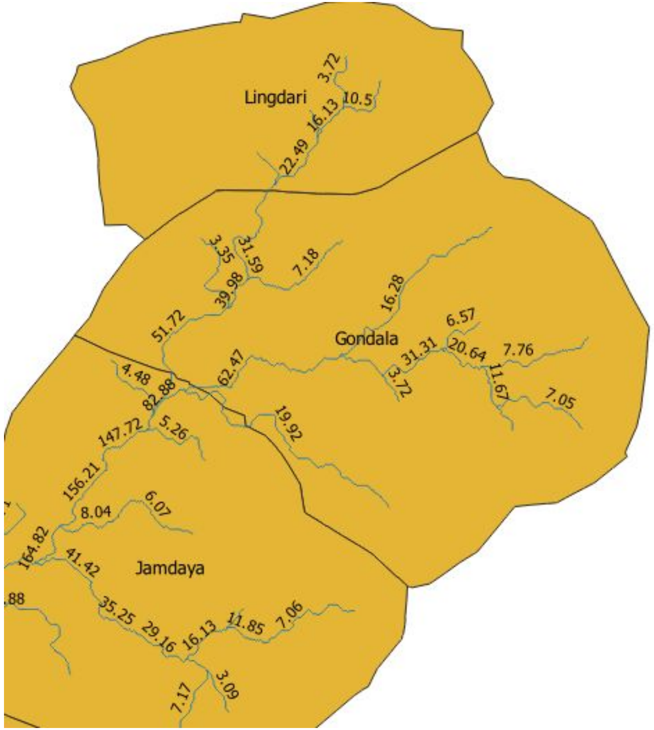
Segment Id(left) and stream order (right)





Slope (left) and peak discharge (right) rate m3/hr (2019)





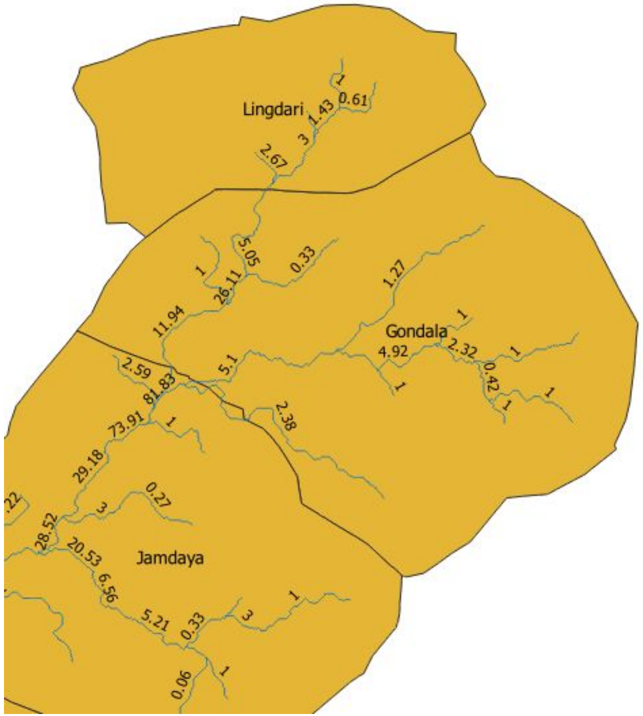
For computation of depth two cases were considered. One with 1 pixel (12.5m) both sides across the stream bed and second with 2 pixels both sides across the stream bed.

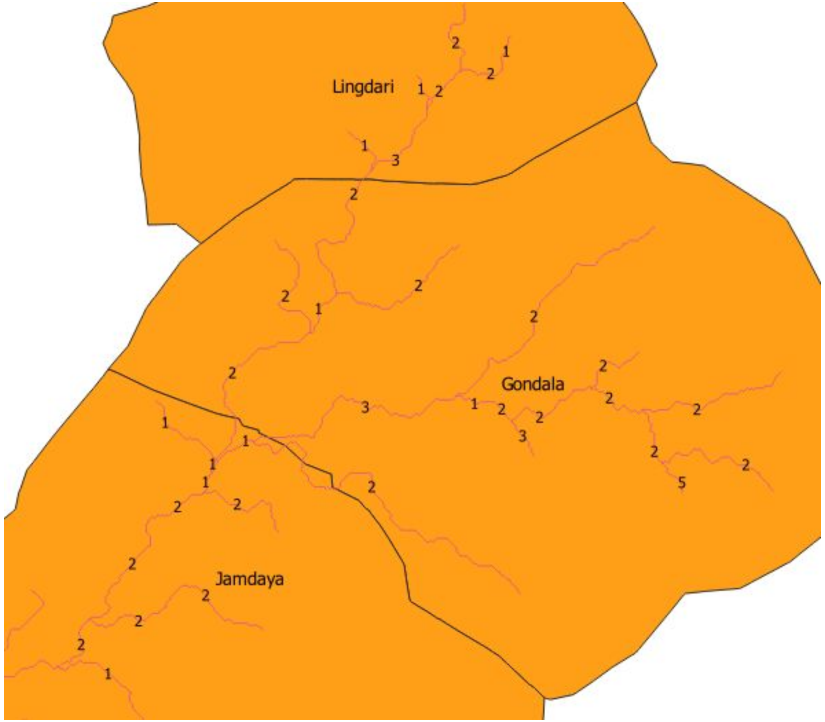
Consider the following segment ids from above slides.

With increase in the depth, width of the stream segment reduces. Similarly with decrease in the depth, width of the segment increases.

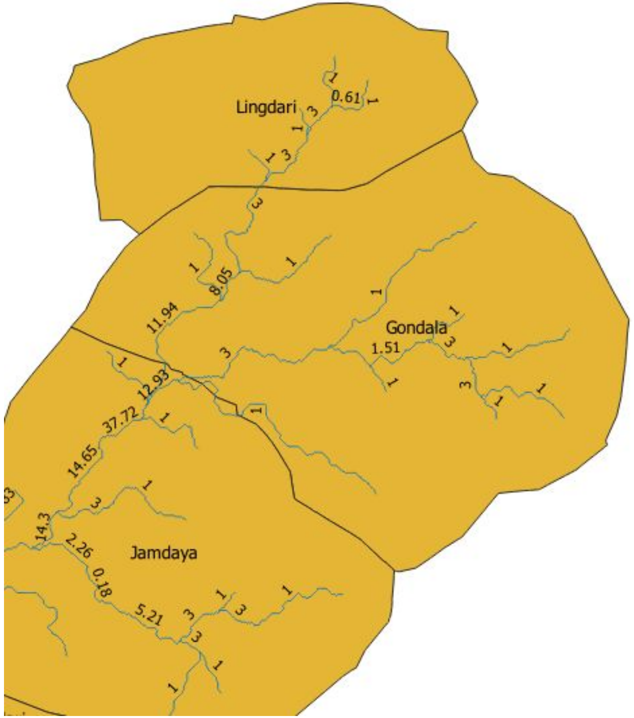
Segment Id	Width Single pixel	Width double pixel	Depth single pixel	Width double pixel
43	1.27	1	2	5
35	5.1	3	3	4

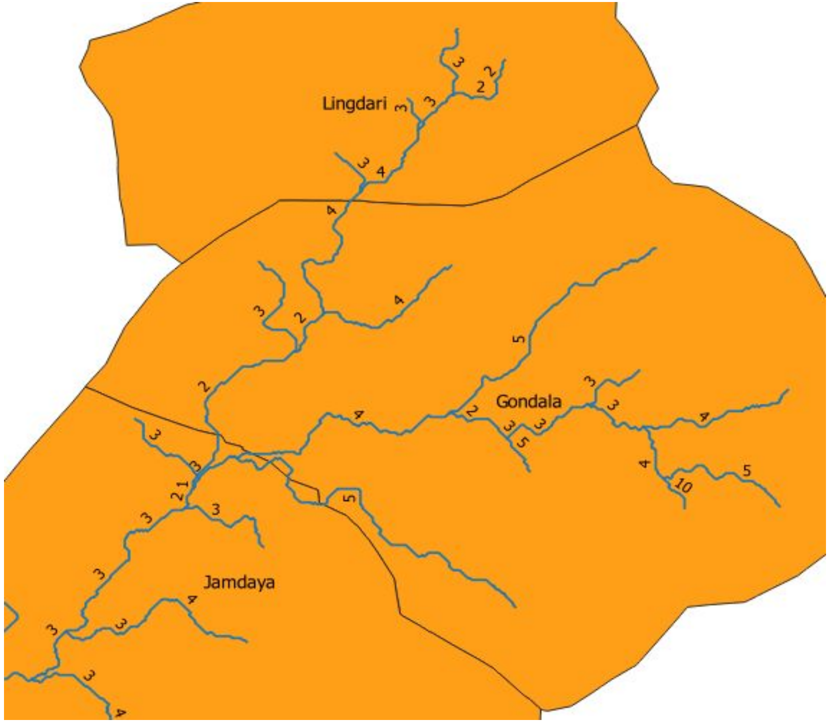
Width (left) and Depth(right) when single pixel is used for depth Calculation (2019)





Width(left) and Depth (right) when double pixel is used for depth calculation (2019)





Runoff balance when depth computed using double pixel (2019)

Rainfall - 1000mm

Sr.No	Year_2019	Lingdari (mm)	Gondala (mm)	Jamdaya (normlized). mm)
1	Area	250 (ha)	1060 (ha)	825 (ha)
2	Runoff_Generated	269	269	269
3	Runoff_In	0	62	392
4	Transmission_loss	6.2	30	41
5	Bank in	3	15	20
6	Return Flow	1	4	5
7	Runoff_Out	264	305	625

Runoff balance when depth computed using single pixel (2019)

Rainfall - 1000mm

Sr.No	Year_2019	Lingdari (mm)	Gondala (mm)	Jamdaya (mm)
1	Area	250 (ha)	1060 (ha)	825 (ha)
2	Runoff_Generated	269	269	269
3	Runoff_In	0	62	383.7
4	Transmission_loss	6.6	37	75
5	Bank in	3.3	18.4	37.4
6	Return Flow	1	4.7	9.7
7	Runoff_Out	264	298.7	587.4

When double pixel was used for depth calculation it reduced the width for the streams. This led to reduction in the wetted perimeter. Hence reduced transmission losses.

When single pixel was used for the depth calculation it increased the width for the streams. More wetted perimeter means more transmission losses in the streams.

As we move from high slope areas (Lingadari) to low slope areas or relatively flatter area transmission losses increased.

There is more water available in stream proximity region in jamdaya village as compared to the lingdari and gondala

Runoff balance when depth computed using single pixel (2018)

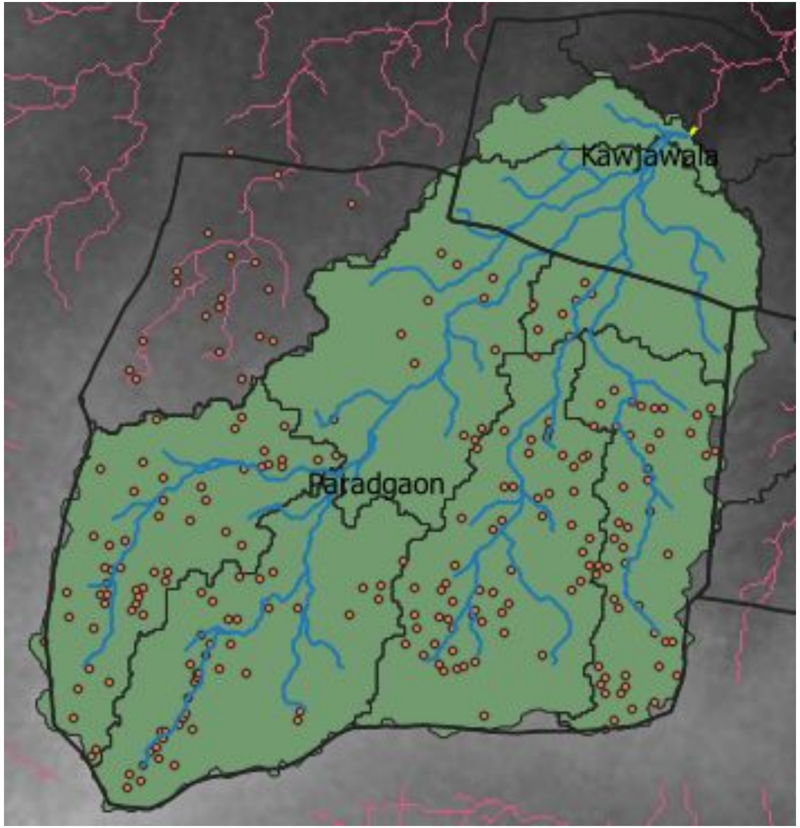
Rainfall - 663mm

Sr.No	Year_2019	Lingdari (mm)	Gondala (mm)	Jamdaya (mm)
1	Area	250 (ha)	1060 (ha)	825 (ha)
2	Runoff_Generated	139	139	139
3	Runoff_In	0	32	208
4	Transmission_loss	2.7	10.2	13.8
5	Bank in	1.3	5.1	6.9
6	Return Flow	0.3	1.3	1.7
7	Runoff_Out	136.5	162	317.7

Runoff and flow events

Segment id	Runoff events	Volume out events	Volume stored events	Year	Village
35	147	276	512	2018	Gondala
21	147	300	521	2018	Jamdaya
35	279	326	975	2019	Gondala
21	279	232	895	2019	Jamdaya
42	102	107	494	2019	Paradgaon

Result for paradgaon village 2019



Sr.No	Year_2019	Paradgaon (mm)
1	Rainfall	868mm
2	Area	2864 (ha)
3	Runoff_Generated	101 mm
4	Runoff_In	0
5	Transmission_loss	56
6	Bank in	28
7	Return Flow	7.2
8	Runoff_Out	52.2

Paradgaon is lot more flatter as compared to the Gondala cluster.

More than 50% area is under cotton crop.

Wells are located in the stream proximity.

50% of runoff water is lost as transmission loss and 50% is going out as runoff.

Pending work

- Two different modules from different sources were used in QGIS for calculation of stream characteristics. There is need to shift the entire routine to modules from single source.
- Considerable recharge in stream proximity is observed in flatter areas, some field validation is required.
- Plugin should be run for last 6 years and based upon the highest runoff width parameter should be computed and fixed permanently for future use.
- More testing is required on different clusters in different geographies.

Limitations in software

In 80% of the cases, the width/depth seems to be in the range as per field observations. Further plugin optimization is required after looking into results from more clusters.