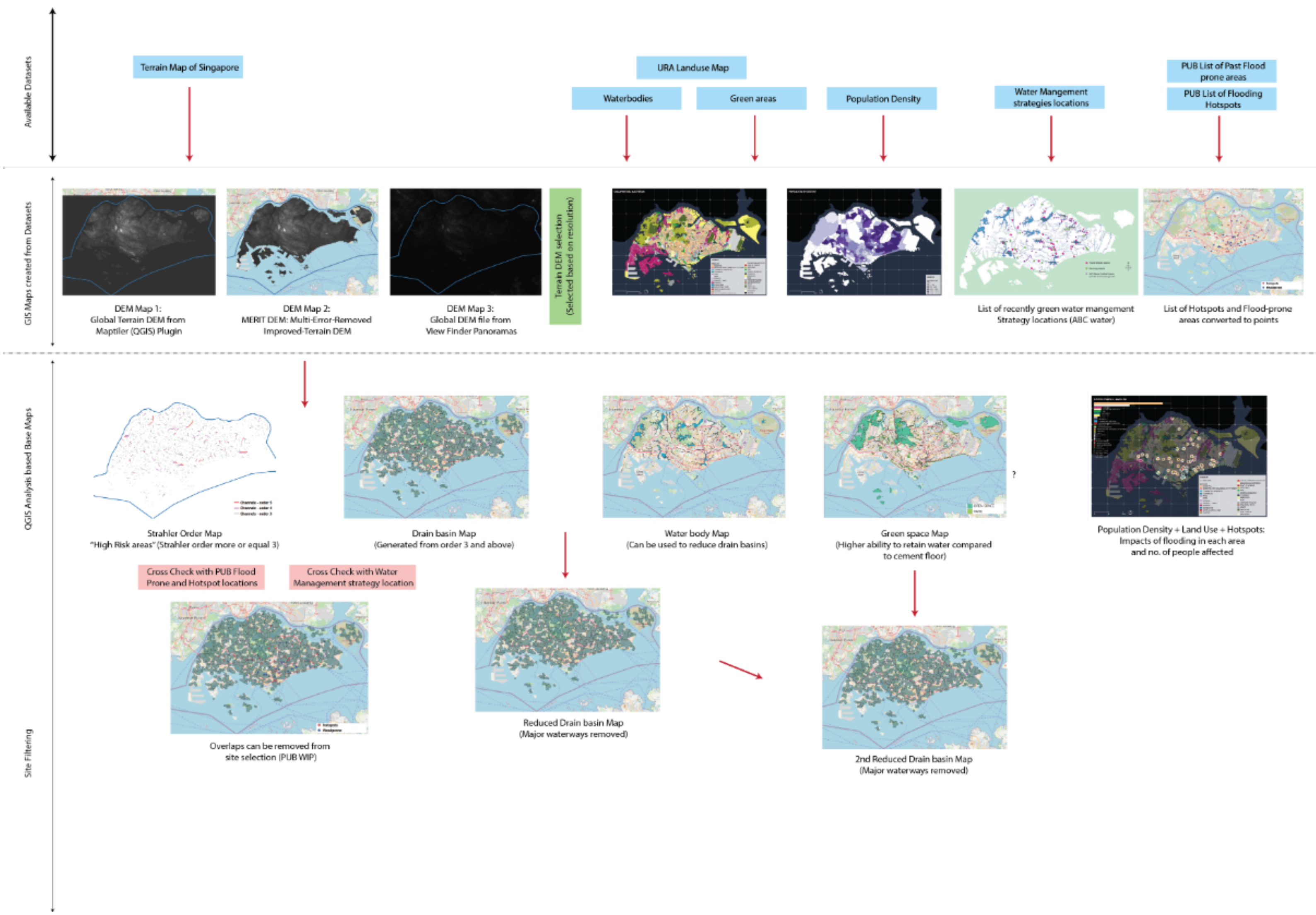
Water Map - Pluvial Flooding

Overall Method of Analysis - Flow Chart



1. Watershed analysis - Strahler Order Map and Drain Basins

Goal: From Topography map, to look for areas with High intensity of flooding.

Higher Strahler Order >> Higher Speed and Intensity of Flooding (due to more streams of water)
Drain Basins >> area of ponding according to the strahler order

Cross check with: (to identify relationships)

- Current flood prone areas and hotspots (for accuracy)

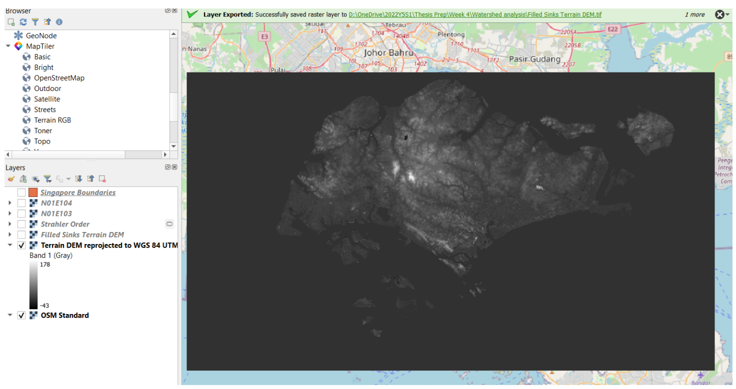
Method of Analysis:
Select sufficiently high resolution terrain DEM >> Watershed analysis >> Strahler Order Map and Drain Basins
>> get: areas with Higher Speed and Intensity of Flooding based on topography and Grid system to evaluate flooding(flood basins).

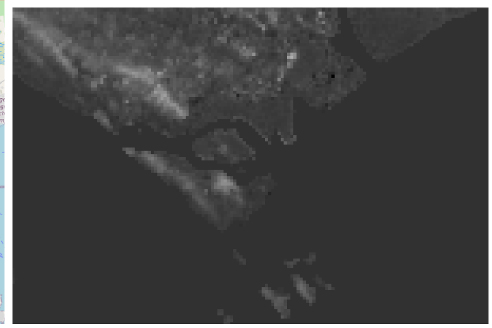
Steps:

1. Choosing a High resolution DEM terrain map of Singapore

Choice of DEM maps:

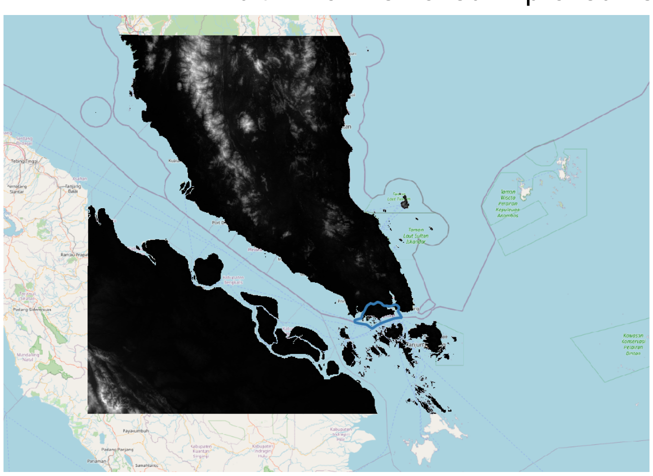
1. Global Terrain DEM from Maptiler (QGIS) Plugin





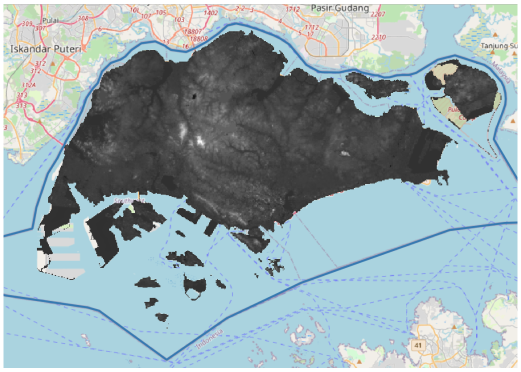
Verdict: Low resolution when zoomed in.

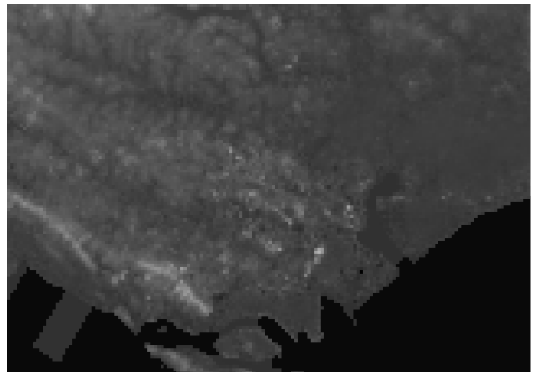
2. MERIT DEM: Multi-Error-Removed Improved-Terrain DEM[1]



Singapore is located in the n00e100 tile.

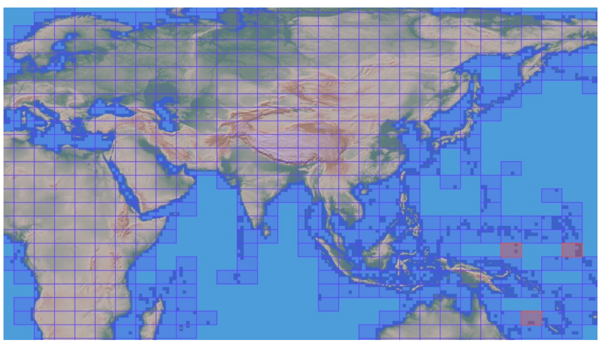
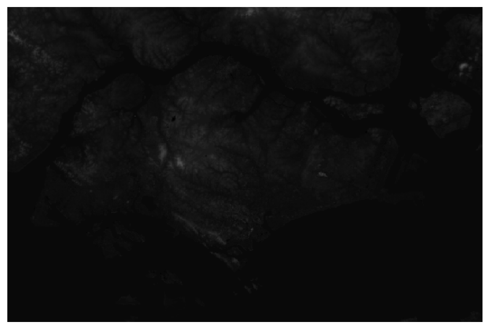
[1] http://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_DEM/index.html





While this DEM dataset lacks data for some of the reclaimed areas, It seemed to the most high resolution out of the 3, sufficient to do flooding analysis for mainland singapore.

3. DEM file from View Finder Panoramas [2]

In this website, global DEM data is provided. Singapore's DEM can be found in the N01E103 and N01E103 Tile.
This DEM data resolution is similar to the Maptiler's DEM data, but much darker.

Conclusion:

DEM Map 2 is Selected for the purpose of the Watershed Analysis.

Resolution of DEM Map 1 and 2 are comparable, DEM Map 3 has been eliminated due to lower resolution/ image being too dark.

Out of DEM map 1 and 2, DEM Map 2 has higher contrast. And due to the development process of DEM Map 2 taking 3 other DEM Maps as reference, It can be assumed that DEM Map 2 has a higher accuracy.

This is supported by the quality of the Strahler order maps generated too. With Map 2 generating the one withthe highest quality.

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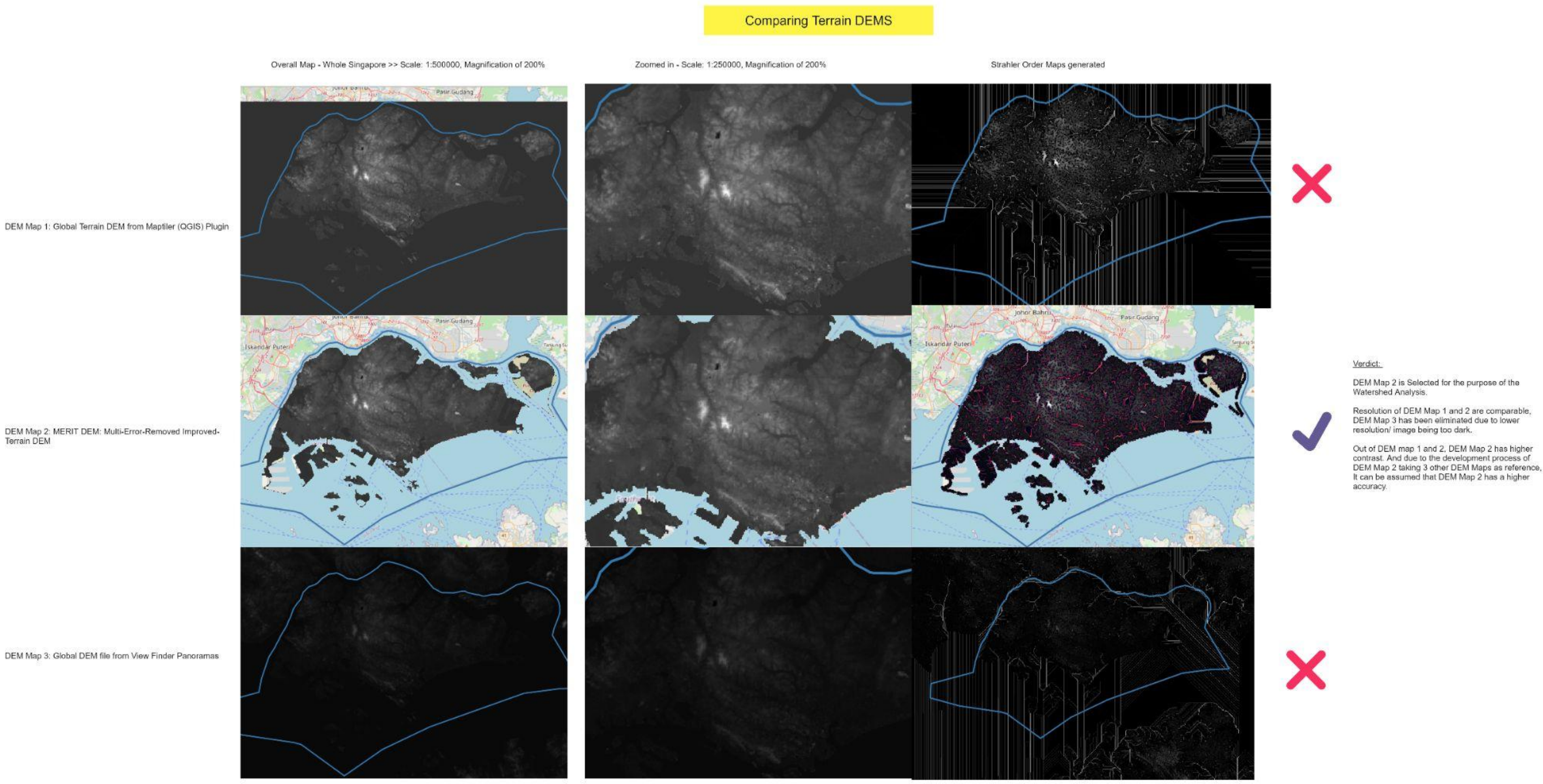
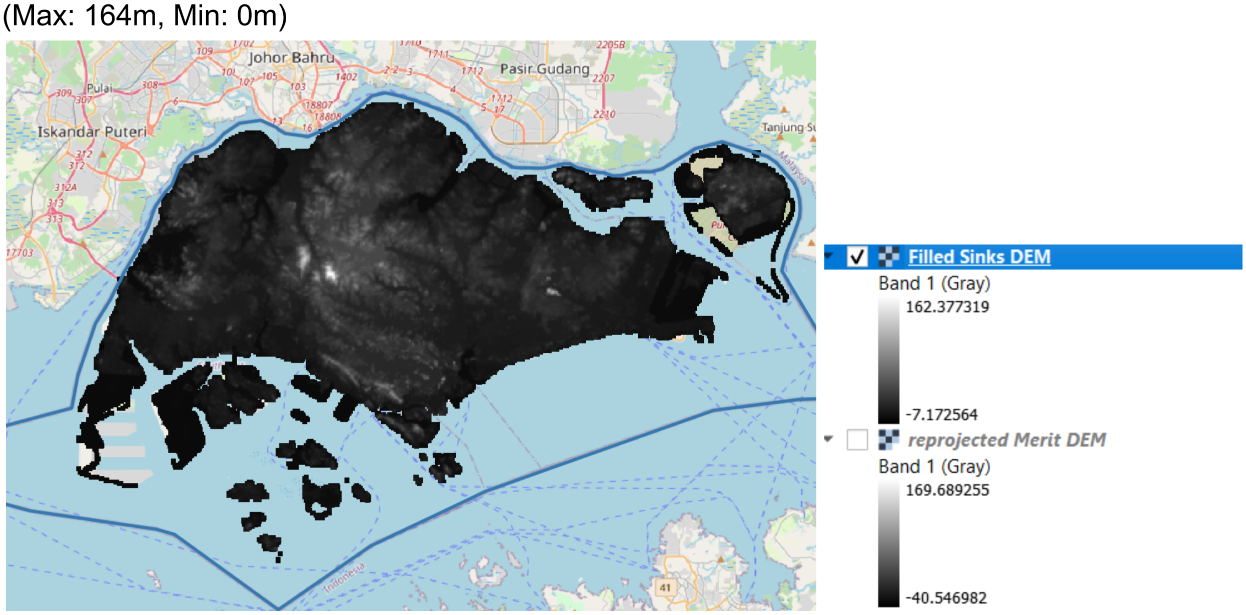
[2] http://viewfinderpanoramas.org/Coverage%20map%20viewfinderpanoramas_org3.htm

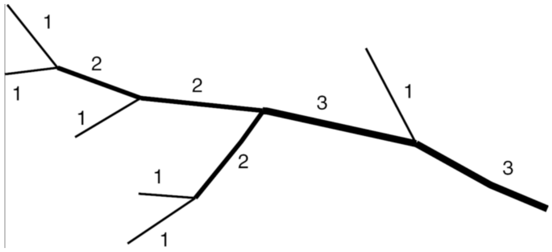


2. Use function “Fill Sinks by Wang and Liu” to remove kinks in the DEM map (while using the Fill Sinks tool seem to produce Fuzzy edges in the DEM map, using the Fill Sinks tool is essential to create a more accurate analysis that omits unwanted kinks from the DEM raster (that is not present in reality)

The “Filled Sinks” values are also closer approximates of actual elevation values in Singapore. (Max: 164m, Min: 0m)

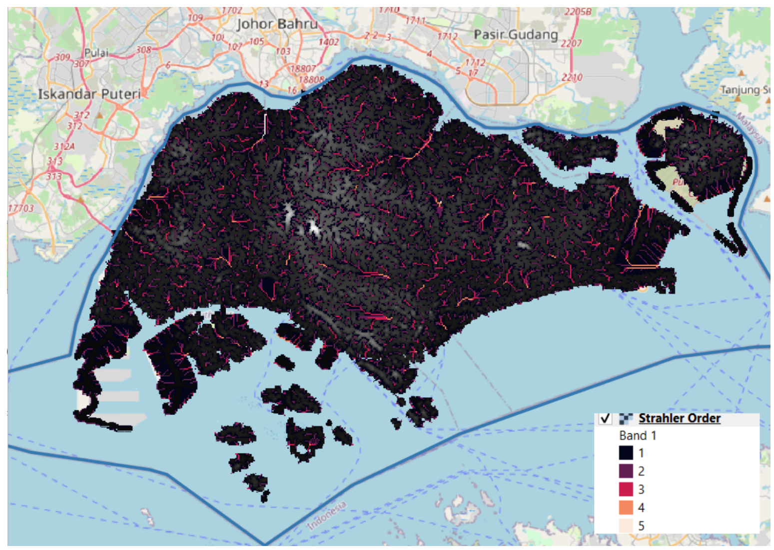


3. Use function “Strahtler Order” to determine how streams of water would flow based on the difference in terrain.

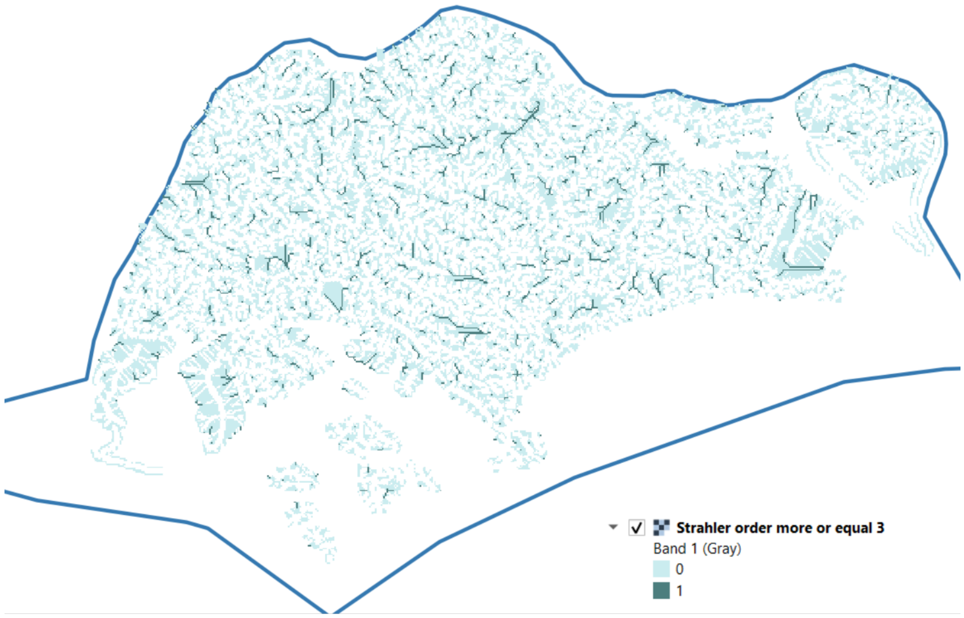


According to the system made by Strahler, rivers of the first order are the outermost tributaries. If two streams of the same order meet, the resulting stream is given a number that is one higher. If two rivers of different stream orders meet, the resulting stream gets the higher of the two numbers. [3]

This can be used to determine the intensity of flooding as higher Strahtler Order would mean more streams of water (from different directions) meet, thus resulting in quicker and more intense flooding. In this Strahtler Order mapping of Singapore, 5 orders have been identified. The lighter the colour, the higher intensity and speed flooding would occur in the area.

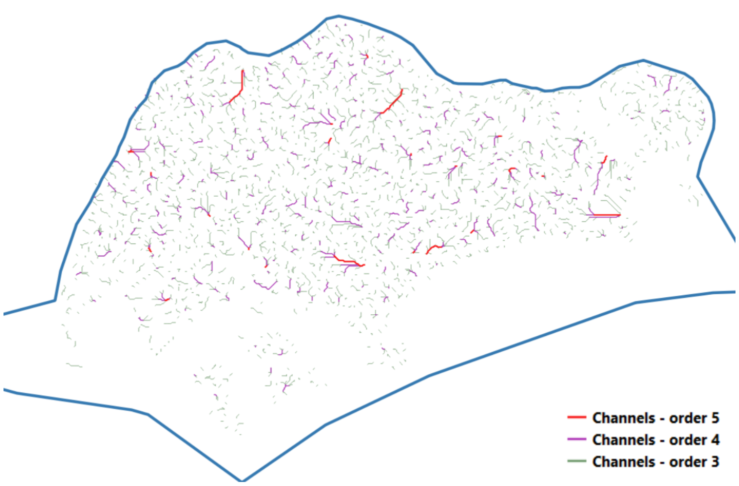


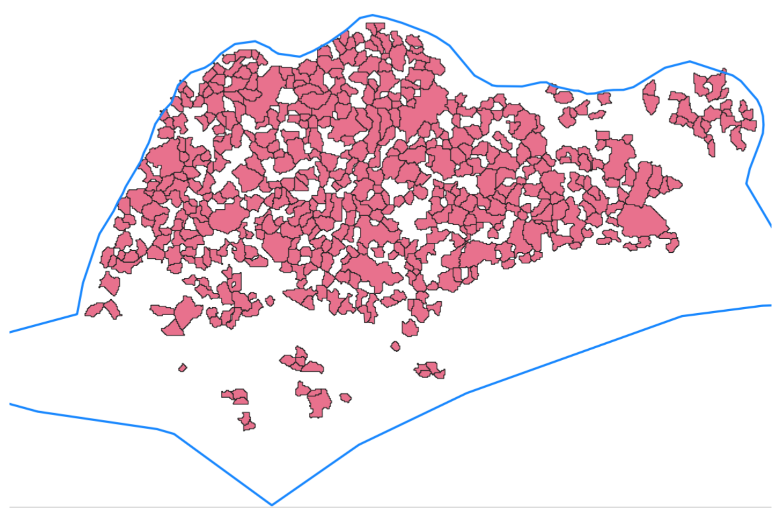
3 https://dges.carleton.ca/CUOSGwiki/index.php/Using_QGIS_to_conduct_watershed_analysis_and_3D_modeling



“High Risk areas” shown in Dark blue (Strahler order more or equal 3)
“Low Risk areas” shown in Light blue (Strahler order 1 and 2)

4. Use function “Channel Network and Drainage Basins” on Filled Sinks DEM to identify water channels. (Vectors) and generate drainage basin vectors.





2. Match base dataset information in the Drainage Basin Polygon Grid

Goal: Map (land use, population density, green map, water management location, hotspot) to the flood basin polygons so that each polygon can be compared.

Method of Analysis:

1. Land use

>> get: Type of Landuse in each DB polygon

>> Waterbodies = area of above a certain % can be eliminated

>> Greens (Parks and Open Spaces) = area of above a certain % can be eliminated

>> Land use Type (Residential/ Industrial etc) = access extent of economic and humanitarian damaged in each DB polygon area.

2. Population Density

>> get: The no. of people affected in each DB polygon.

3. PUB list of Floodprone areas and Hotspots

>> get: Existing risk of flooding in each polygon

4. ABC water management locations and methods

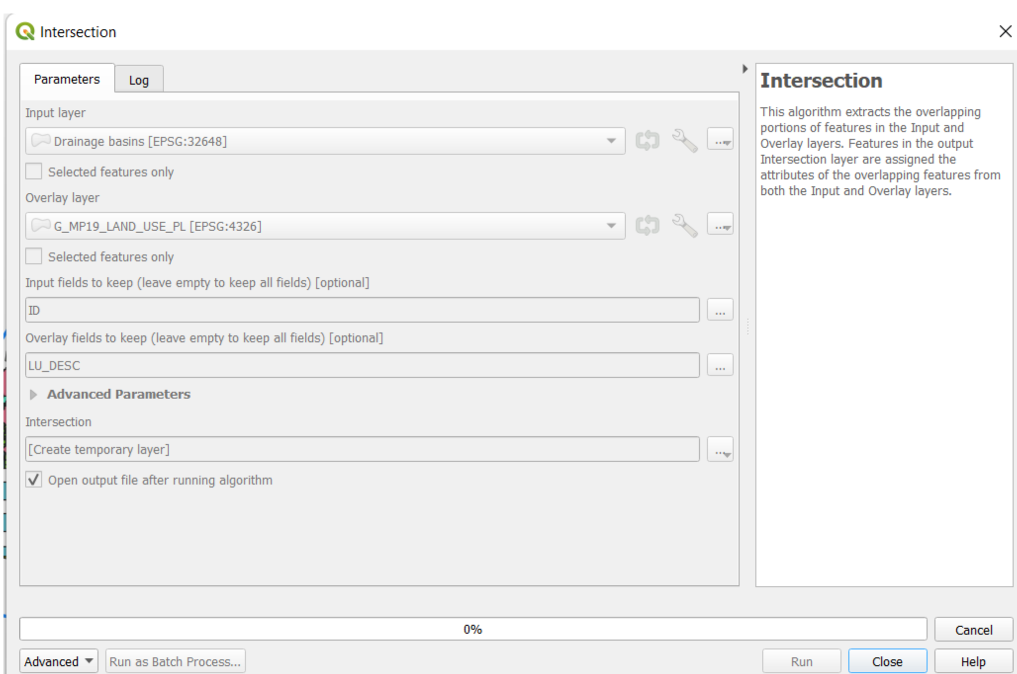
>> get: Areas that have been adequately dealt with by updated and sustainable measures.

2.1 Land use mapped to DB grid

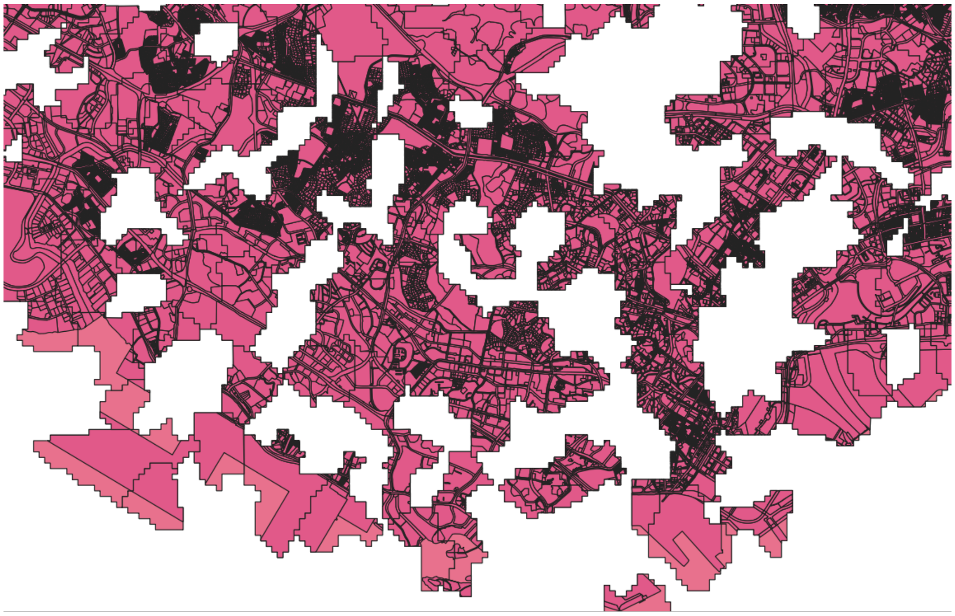
Steps:

1. Finding percentage of area of each type of Land use in a DB polygon.

Intersect landuse (fixed geometries) and DB, keeping DB ID and Landuse.

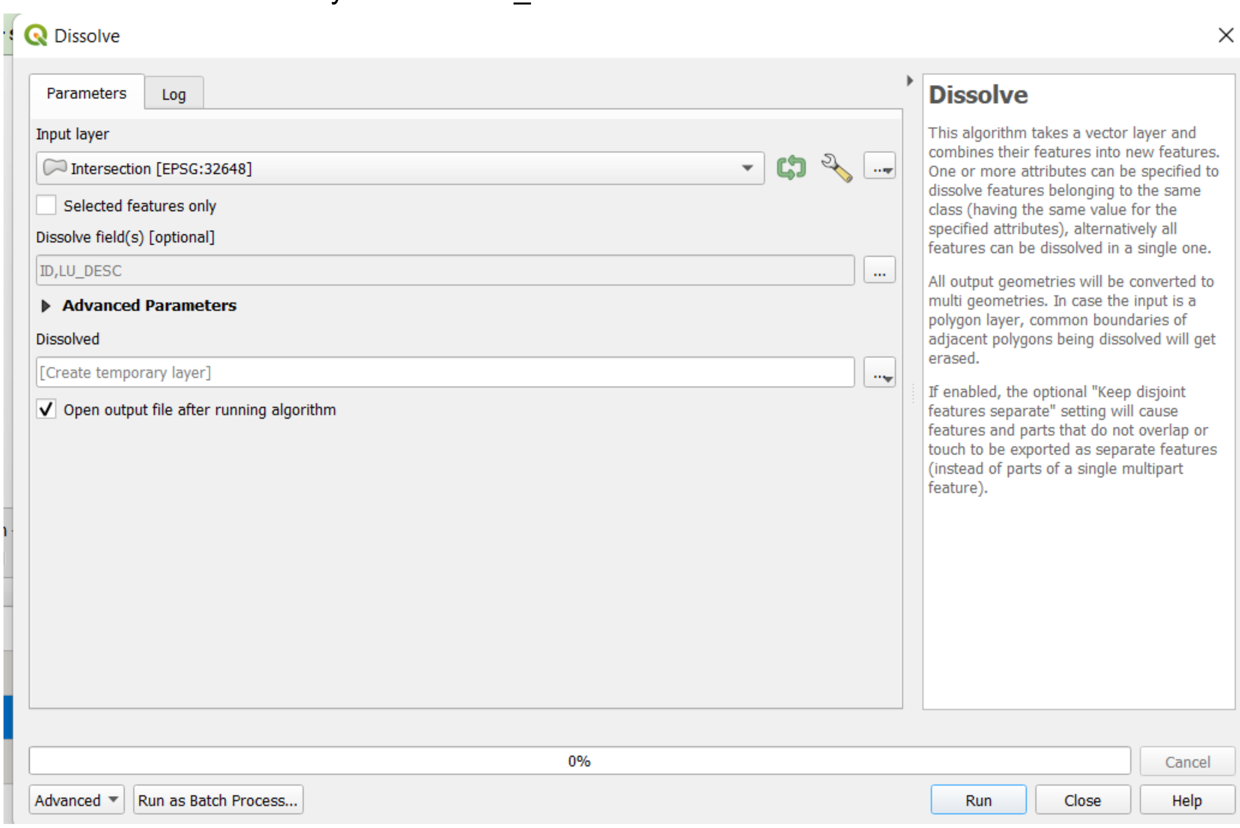


Result: Isolating landuse data (LU_DESC) to each DB polygon (ID)

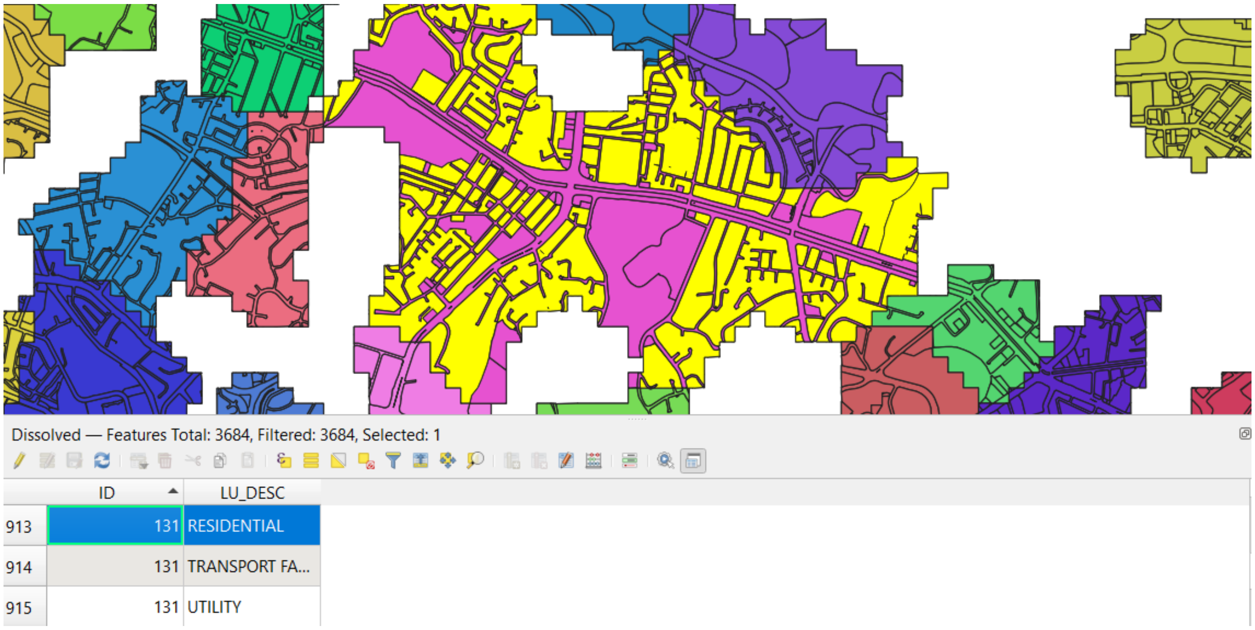


	ID	LU_DESC
1	0	OPEN SPACE
2	1	OPEN SPACE
3	1	OPEN SPACE
4	2	OPEN SPACE
5	3	UTILITY
6	4	BUSINESS 2
7	5	OPEN SPACE

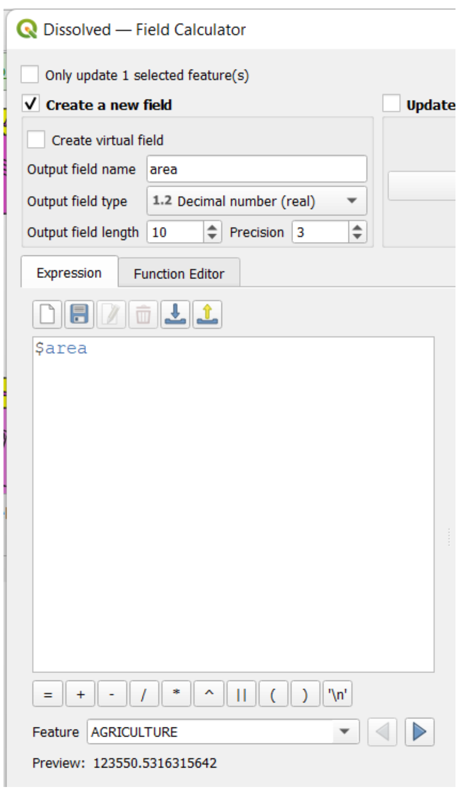
- Dissolve “intersection” by “ID” and “LU_DESC”

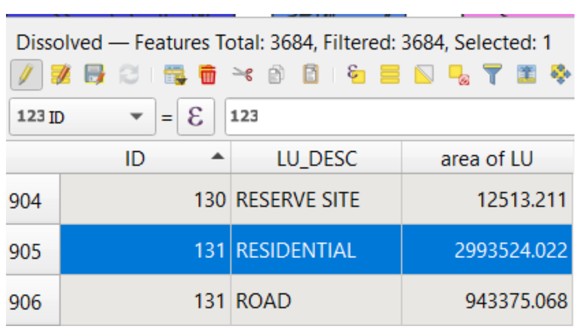


Result: all landuse polygons within a single grid are grouped tgt



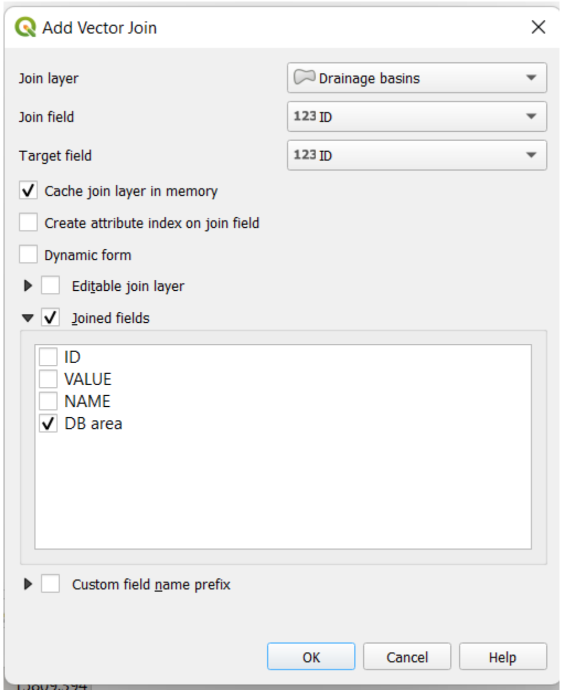
- find area of each LU_DESC





Result: “area of LU” column created

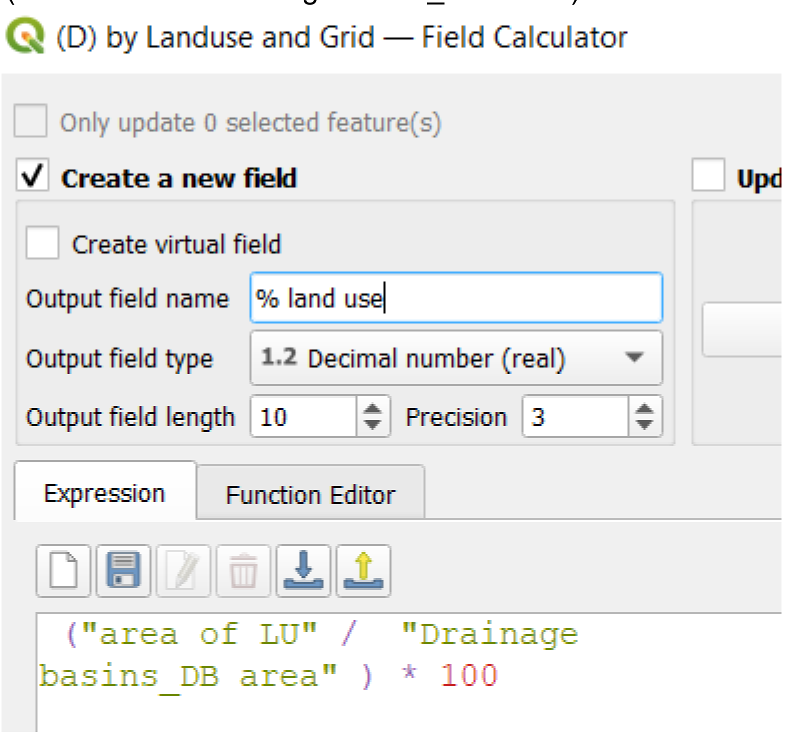
- Join DB areas as a new column



	ID	LU_DESC	area of LU	Drainage basins_DB area
724	113	WATERBODY	26820.023	1380270.473
725	113	TRANSPORT FA...	6066.174	1380270.473
726	113	BUSINESS 2	1090147.337	1380270.473
727	113	UTILITY	15809.394	1380270.473
728	114	ROAD	239975.882	1946168.767
729	114	WATERBODY	15079.659	1946168.767
730	114	COMMERCIAL	3013.200	1946168.767

Result: “DB area” column added

- create “% land use” as a column, Query:
 ("area of LU" / "Drainage basins_DB area") * 100



	ID	LU_DESC	area of LU	Drainage basins_DB area	% land use
1	0	OPEN SPACE	319852.057	454407.911	70.389
2	1	OPEN SPACE	249227.622	583012.583	42.748
3	2	OPEN SPACE	79840.118	505847.983	15.783
4	3	UTILITY	2266926.035	2580793.542	87.838
5	4	BUSINESS 2	131366.155	445857.636	29.464
6	5	OPEN SPACE	752683.197	771631.723	97.544
7	6	UTILITY	343725.066	445850.215	77.094
8	7	OPEN SPACE	197370.295	454402.365	43.435
9	8	OPEN SPACE	370587.568	865972.534	42.794
10	8	UTILITY	67611.070	865972.534	7.808
11	9	BEACH AREA	13895.848	420155.564	7.808
12	9	SPORTS & RECREATION	60396.691	420155.564	14.375
13	9	PLACE OF WORSHIP	474.293	420155.564	0.113
14	9	UTILITY	1761.300	420155.564	0.419
15	10	BUSINESS 2	115185.549	231481.969	49.760
16	11	BUSINESS 2	449237.894	1080328.358	41.583

2. Grouping area according to class

Facilities Categories:[4]

(Class 1) Highest Risk - Residential buildings
Residential with commercial 1st storey (Shophouseish) + Residential + Residential/ Institution

(Class 2) High Risk - Humanitarian + Other Essential Facilities
Civic & Community Institution + Health & Medical Care + Utility + Educational institutes

(Class 3) Medium Risk - Transport Facilities
Road + Transport Facilities + Rapid Transit + Port/Airport

(Class 4) Low risk to human lifes, High economic damages - Economic Facilities
Commercial & Residential (shopping mall + condo) + Commercial
Business Park + Business Park - White
Business 1 (B1) + Business 1 - White + Business 2 (B2) + Business 2 - White
+ Agriculture + Hotel

[4] URA Land Use Categories - THE PLANNING ACT MASTER PLAN WRITTEN STATEMENT 2019

(Class 5) Lowest Risk - Social Facilities
Cultural and heritage, Religious (cemetery, Place of worship), Leisure and Entertainment, Sports and Recreation, Beach area

(Reserve Sites, Special Uses and White Sites not included)
(Parks, Open Spaces (Class 6) and Waterbodies mapped as separate categories)

- Assign class for each via Filter selected features >> Field Calculator

	ID	LU_DESC	area of LU	Drainage basins_DB area	% land use	Class
1	0	OPEN SPACE	319852.057	454407.911	70.389	6
2	1	OPEN SPACE	249227.622	583012.583	42.748	6
3	2	OPEN SPACE	79840.118	505847.983	15.783	6
4	3	UTILITY	2266926.035	2580793.542	87.838	2
5	4	BUSINESS 2	131366.155	445857.636	29.464	4
6	5	OPEN SPACE	752683.197	771631.723	97.544	6
7	6	UTILITY	343725.066	445850.215	77.094	2

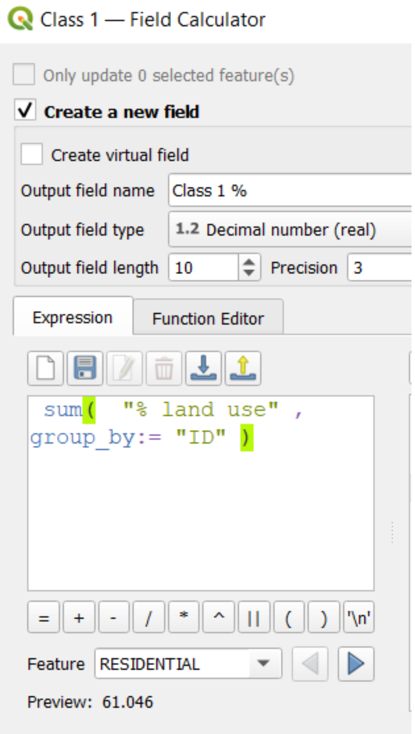
- However, landuse % are not by grid yet, take DB grid no.131 for example, while “Residential with commercial on 1st storey” and “Residential” are both Class 1, they need to be added to produce the overall landuse% for Class 1 in DB grid no.131.

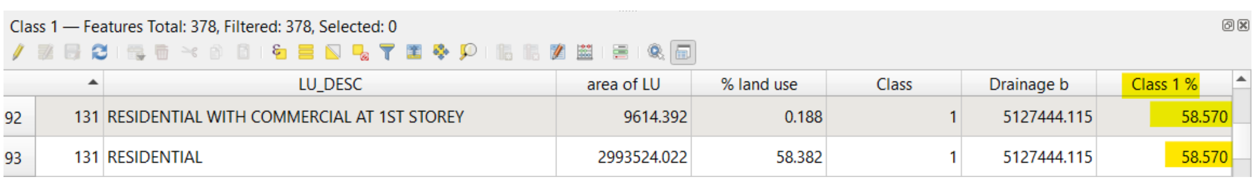
(D) by Landuse and Grid — Features Total: 3684, Filtered: 3684, Selected: 0

	ID	LU_DESC	area of LU	Drainage basins_DB area	% land use	Class
907	131	WATERBODY	91490.264	5127444.115	1.784	NULL
908	131	RESIDENTIAL WITH COM...	9614.392	5127444.115	0.188	1
909	131	RESIDENTIAL	2993524.022	5127444.115	58.382	1
910	131	EDUCATIONAL INSTITUTION	582469.793	5127444.115	11.360	2
911	131	CIVIC & COMMUNITY INST...	11865.315	5127444.115	0.231	2
912	131	UTILITY	11445.845	5127444.115	0.223	2
913	131	HEALTH & MEDICAL CARE	1818.167	5127444.115	0.035	2
914	131	TRANSPORT FACILITIES	6624.033	5127444.115	0.129	3
915	131	ROAD	943375.068	5127444.115	18.399	3
916	131	COMMERCIAL & RESIDEN...	21025.894	5127444.115	0.41	4
917	131	COMMERCIAL	8657.788	5127444.115	0.169	4
918	131	SPORTS & RECREATION	12311.481	5127444.115	0.24	5
919	131	PLACE OF WORSHIP	14010.803	5127444.115	0.273	5
920	131	PARK	372623.899	5127444.115	7.267	6

- To do this, we can first export each layer separately for each class, then create a new field “Class %” to get the overall landuse % of each class.

Use field calculator, Query >> sum("% land use" , group_by:= "ID") in each class layers.



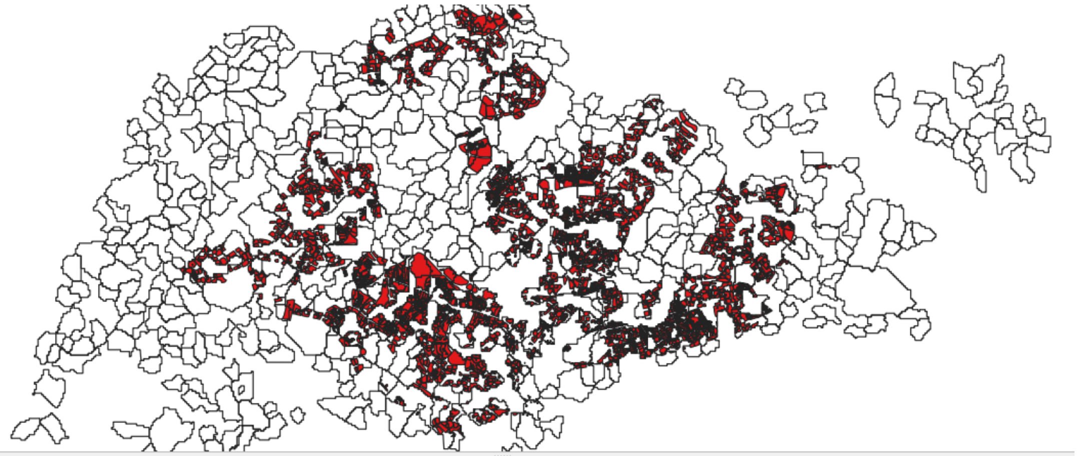

Class 1 — Features Total: 378, Filtered: 378, Selected: 0

		LU_DESC	area of LU	% land use	Class	Drainage b	Class 1 %
92	131	RESIDENTIAL WITH COMMERCIAL AT 1ST STOREY	9614.392	0.188	1	5127444.115	58.570
93	131	RESIDENTIAL	2993524.022	58.382	1	5127444.115	58.570

Result: We now have a column “Class 1 %” that we can use to visualise the datas.

- This process is then repeated for all the classes, and also for greenareas and waterbodies.

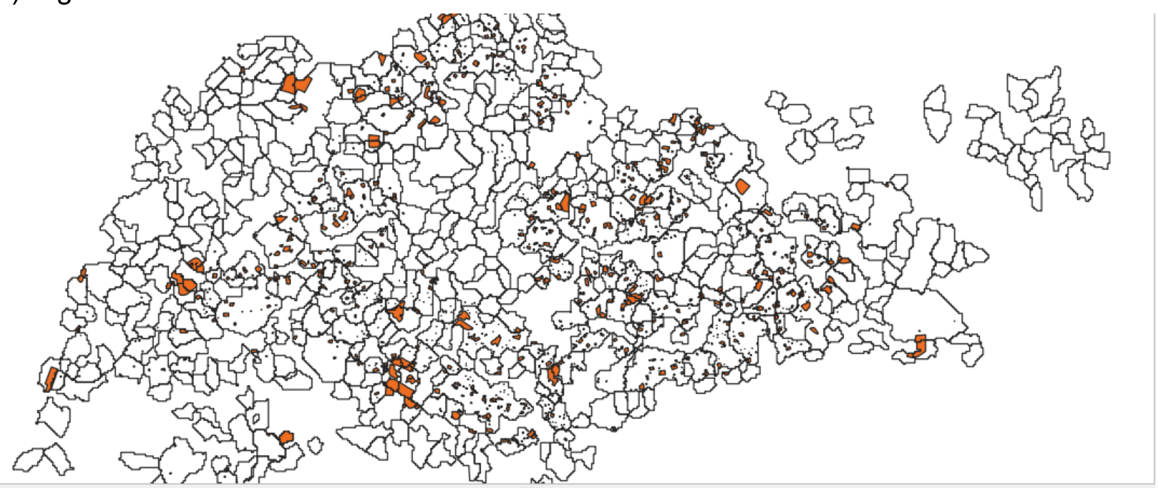
(Class 1) Highest Risk - Residential buildings



Class 1 — Features Total: 378, Filtered: 378, Selected: 0

		LU_DESC	area of LU	% land use	Class	Drainage b	Class 1 %
1	19	RESIDENTIAL	21045.972	5.578	1	377274.039	5.578
2	21	RESIDENTIAL	111533.359	8.614	1	1294745.606	8.614
3	25	RESIDENTIAL	279121.989	35.004	1	797407.498	35.004
4	27	RESIDENTIAL	464142.019	37.077	1	1251848.603	37.400
5	27	RESIDENTIAL WITH COMMERCIAL AT 1ST STOREY	4039.605	0.323	1	1251848.603	37.400

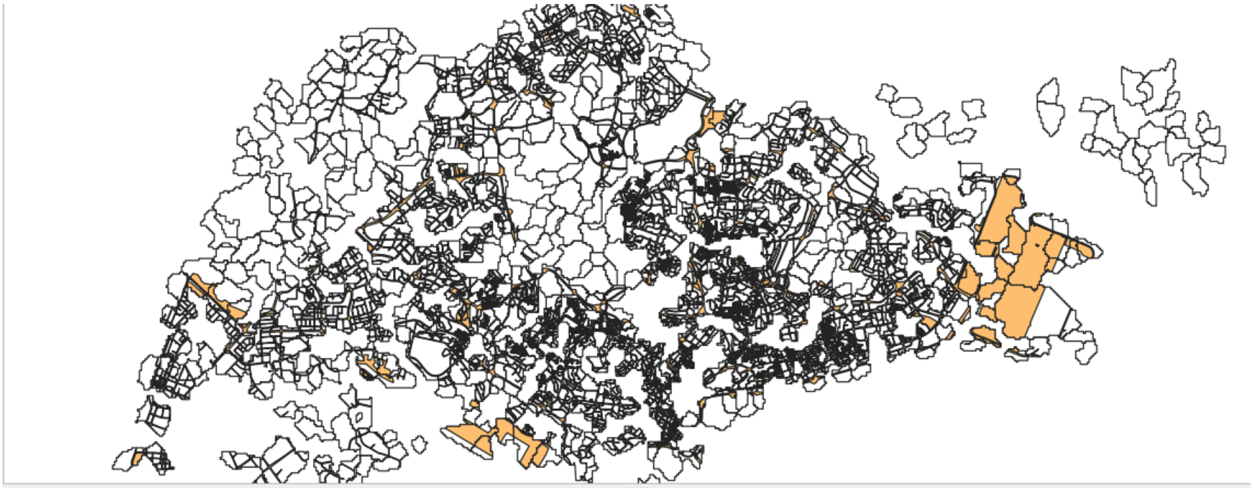
(Class 2) High Risk - Humanitarian + Other Essential Facilities



Class 2 — Features Total: 664, Filtered: 664, Selected: 0

		LU_DESC	area of LU	% land use	Class	Drainage b	Class 2 %
1	3	UTILITY	2266926.035	87.838	2	2580793.542	87.838
2	6	UTILITY	343725.066	77.094	2	445850.215	77.094
3	8	UTILITY	67611.070	7.808	2	865972.534	7.808
4	9	UTILITY	1761.300	0.419	2	420155.564	0.419
5	12	UTILITY	14522.098	3.321	2	437301.490	3.321

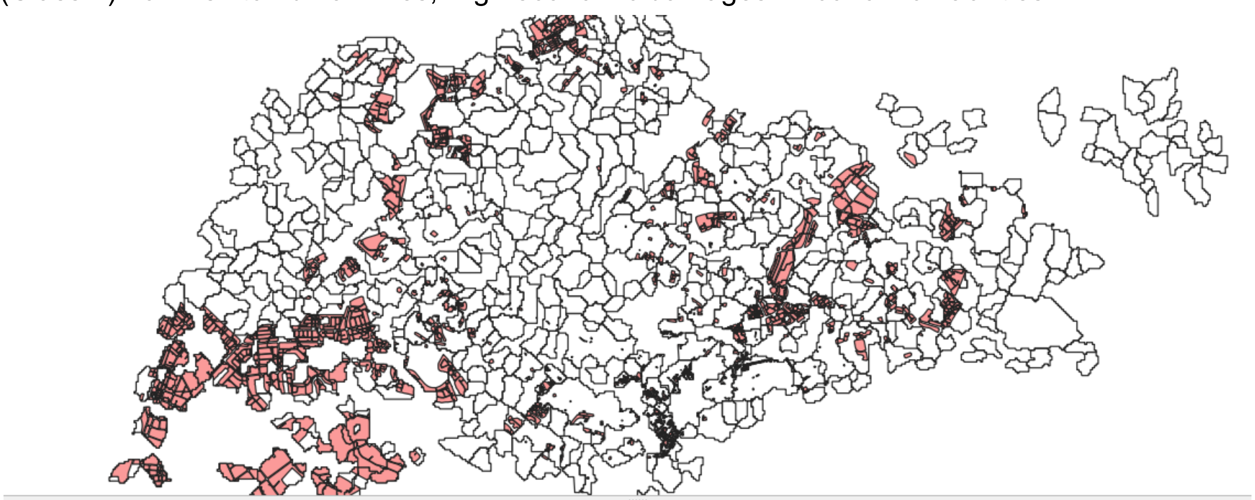
(Class 3) Medium Risk - Transport Facilities



Class 3 — Features Total: 594, Filtered: 594, Selected: 0

	ID	LU_DESC	area of LU	% land use	Class	Drainage b	Class 3 %
1	328	LIGHT RAPID TRANSIT	853.000	0.199	3	428700.358	19.949
2	324	LIGHT RAPID TRANSIT	3482.383	0.149	3	2340691.371	20.964
3	330	LIGHT RAPID TRANSIT	2851.289	0.135	3	2117949.088	24.567
4	383	LIGHT RAPID TRANSIT	2551.632	0.431	3	591664.493	22.690

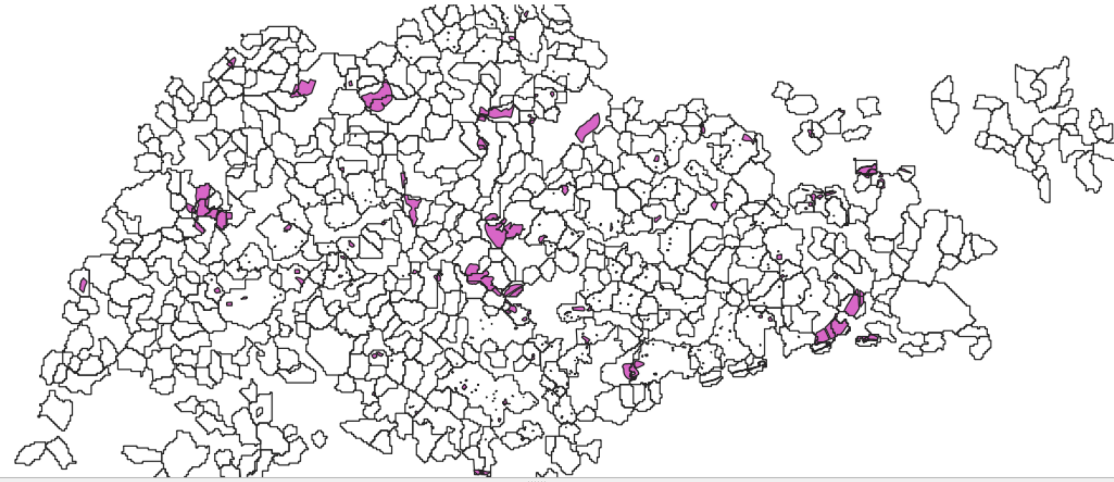
(Class 4) Low risk to human lives, High economic damages - Economic Facilities



Class 4 — Features Total: 539, Filtered: 539, Selected: 0

	ID	LU_DESC	area of LU	% land use	Class	Drainage b	Class 4 %
26	457	COMMERCIAL & RESIDENTIAL	8544.983	3.020	4	282954.024	3.020
27	456	BUSINESS 1	26391.009	1.368	4	1929175.064	17.892
28	456	BUSINESS 1 - WHITE	608.306	0.032	4	1929175.064	17.892
29	456	BUSINESS 2	203996.540	10.574	4	1929175.064	17.892
30	456	COMMERCIAL	74592.305	3.867	4	1929175.064	17.892

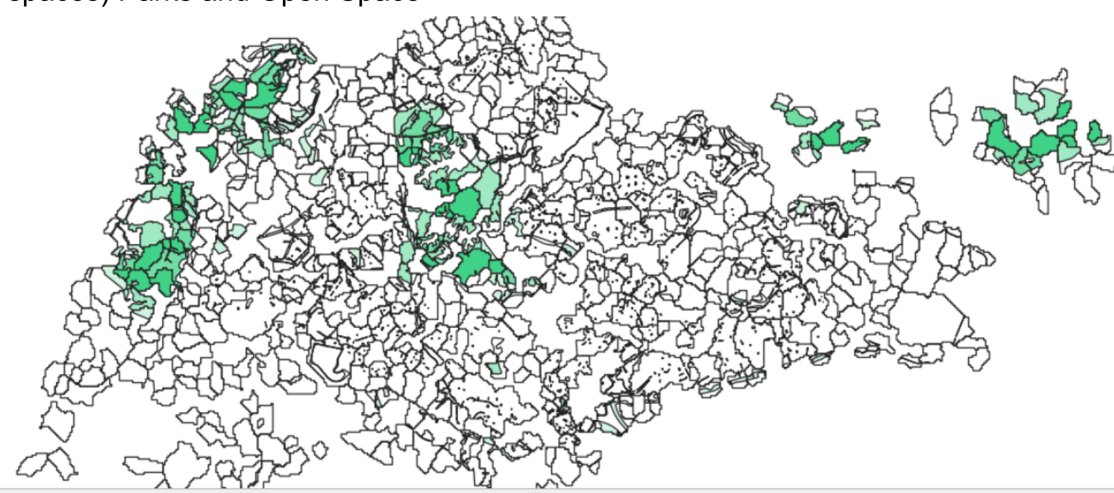
(Class 5) Lowest Risk - Social Facilities



Class 5 — Features Total: 287, Filtered: 287, Selected: 0

	ID	LU_DESC	area of LU	% land use	Class	Drainage b	Class 5 %
1	9	BEACH AREA	13895.848	3.307	5	420155.564	17.795
2	9	PLACE OF WORSHIP	474.293	0.113	5	420155.564	17.795
3	9	SPORTS & RECREATION	60396.691	14.375	5	420155.564	17.795
4	12	BEACH AREA	9785.069	2.238	5	437301.490	9.311
5	12	SPORTS & RECREATION	30930.248	7.073	5	437301.490	9.311

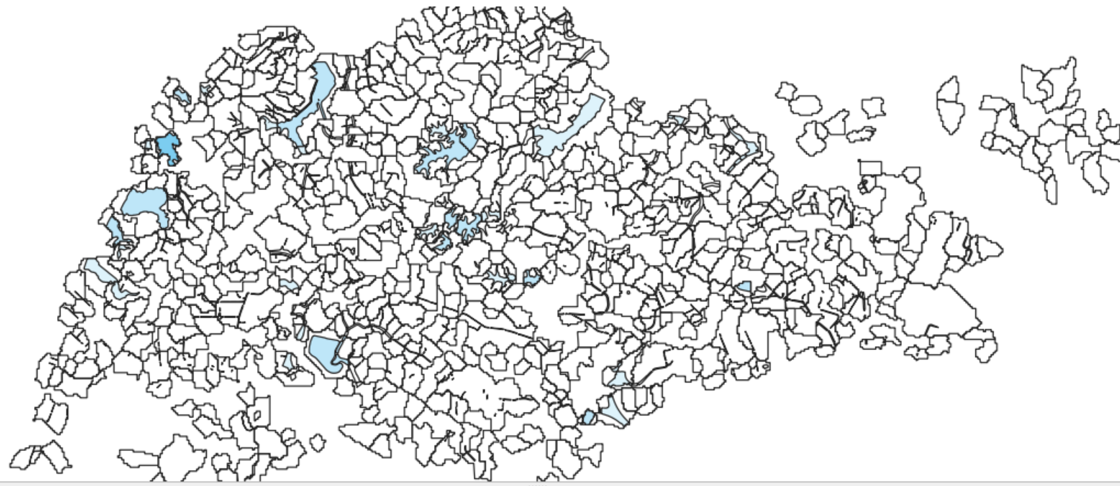
(Green spaces) Parks and Open Space



Green areas — Features Total: 523, Filtered: 523, Selected: 0

	ID	LU_DESC	area of LU	% land use	Class	Drainage b	% Green
1	0	OPEN SPACE	319852.057	70.389	6	454407.911	70.389
2	1	OPEN SPACE	249227.622	42.748	6	583012.583	42.748
3	2	OPEN SPACE	79840.118	15.783	6	505847.983	15.783
4	5	OPEN SPACE	752683.197	97.544	6	771631.723	97.544

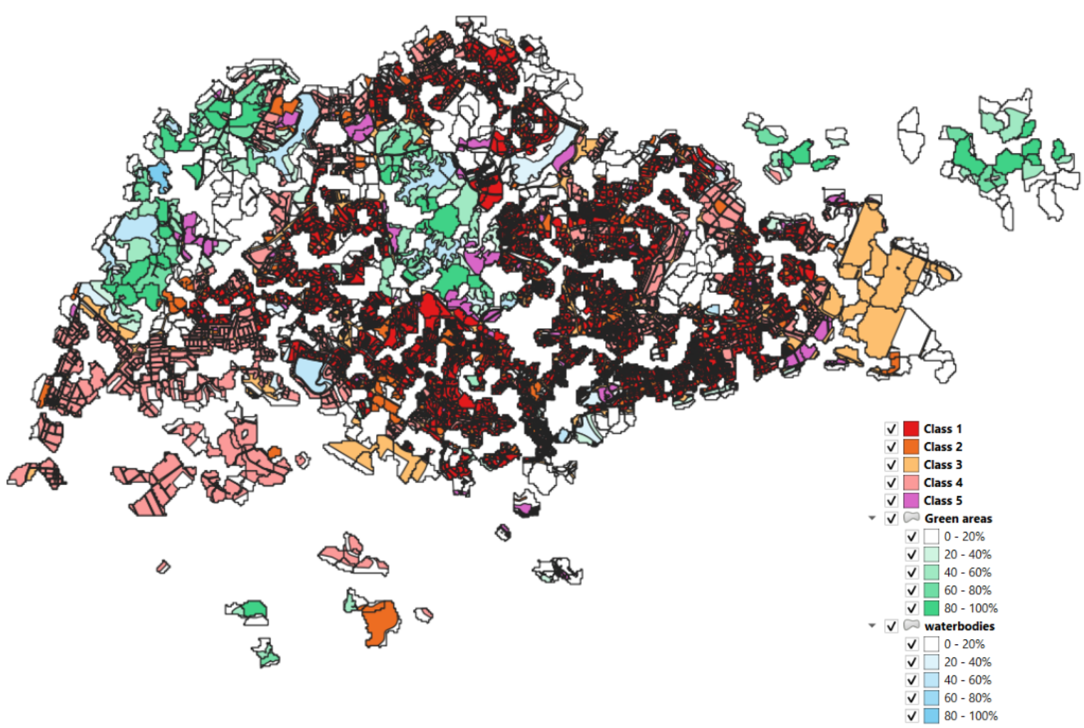
(Waterbodies)



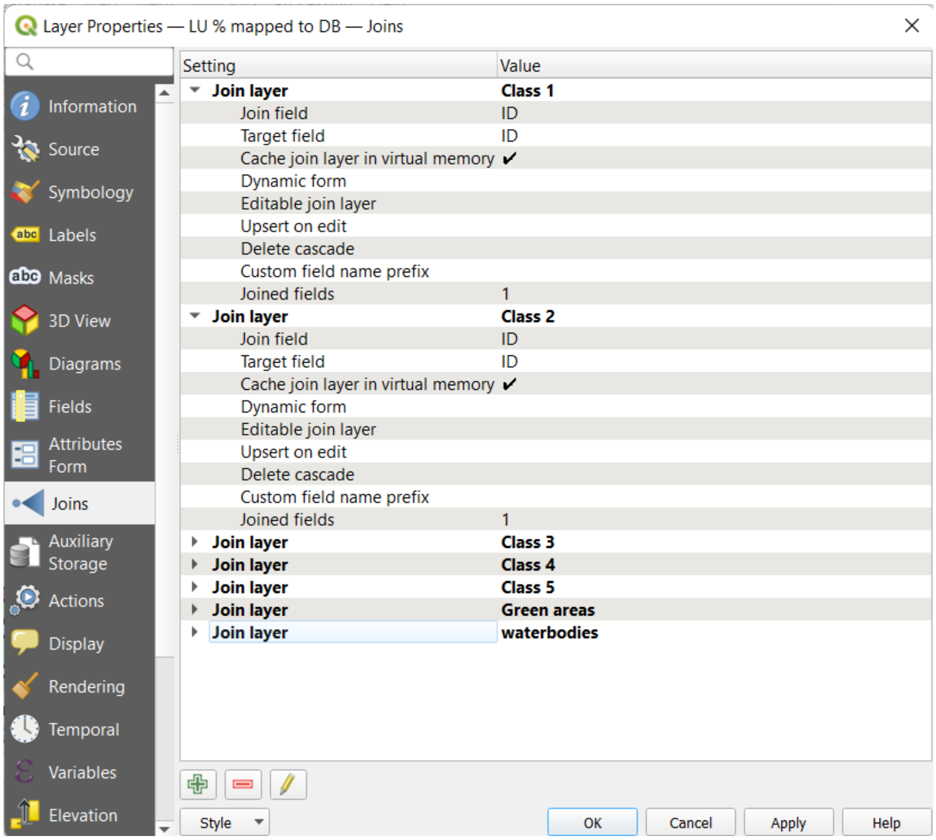
waterbodies — Features Total: 300, Filtered: 300, Selected: 0

	ID	LU_DESC	area of LU	Class	Drainage b	% land use
13	51	WATERBODY	12790.177	NULL	1766046.049	0.724
14	52	WATERBODY	279373.938	NULL	471601.484	59.239
15	57	WATERBODY	48167.387	NULL	960284.698	5.016
16	58	WATERBODY	43284.835	NULL	1106112.435	3.913
17	60	WATERBODY	25038.302	NULL	523043.269	4.787

Overview of all landuse mapped to drain basins



3. Consolidate Class data for each DB grid and Map back to the “Drain Basin Grid” Layer



LU % mapped to DB — Features Total: 478, Filtered: 478, Selected: 0

	ID	VALUE	NAME	DB area	Class 1_Class 1 %	Class 2_Class 2 %	Class 3_Class 3 %	Class 4_Class 4 %	Class 5_Class 5 %	een areas_% Gre	waterbodies_% land use
1	0	1	1	454407.911	NULL	NULL	NULL	NULL	NULL	70.389	NULL
2	1	2	2	583012.583	NULL	NULL	NULL	NULL	NULL	42.748	NULL
3	2	3	3	505847.983	NULL	NULL	NULL	NULL	NULL	15.783	NULL

Result: Columns are added in the attribute table

- Find the Class that has the highest %landuse in each DB grid

In field calculator, create a new column called “MAX”, Query:

max ("Class 1_Class 1 %" , "Class 2_Class 2 %" , "Class 3_Class 3 %" , "Class 4_Class 4 %" , "Class 5_Class 5 %", "Green areas_% Green" , "waterbodies_% land use")

LU % mapped to DB — Features Total: 478, Filtered: 478, Selected: 0

	ID	VALUE	NAME	DB area	Class 1_Class 1 %	Class 2_Class 2 %	Class 3_Class 3 %	Class 4_Class 4 %	Class 5_Class 5 %	een areas_% Gre	waterbodies_% land use	MAX
1	0	1	1	454407.911	NULL	NULL	NULL	NULL	NULL	70.389	NULL	70.389
2	1	2	2	583012.583	NULL	NULL	NULL	NULL	NULL	42.748	NULL	42.748
3	2	3	3	505847.983	NULL	NULL	NULL	NULL	NULL	15.783	NULL	15.783

Result: “MAX” column is added in the attribute table, showing the maximum landuse% in each DB grid (ID).

- Map maximum value %landuse in each grid to the column, so that we can understand and visualise which class is of the highest % in each DB grid.

In Field calculator, create a new field “ MAX class” , Query:

Case
when "Class 1_Class 1 %" = max ("Class 1_Class 1 %" , "Class 2_Class 2 %" , "Class 3_Class 3 %" , "Class 4_Class 4 %" , "Class 5_Class 5 %", "Green areas_% Green" , "waterbodies_% land use") THEN 'Class 1'

when "Class 2_Class 2 %" = max ("Class 1_Class 1 %" , "Class 2_Class 2 %" , "Class 3_Class 3 %" , "Class 4_Class 4 %" , "Class 5_Class 5 %", "Green areas_% Green" , "waterbodies_% land use") THEN 'Class 2'

when "Class 3_Class 3 %" = max ("Class 1_Class 1 %" , "Class 2_Class 2 %" , "Class 3_Class 3 %" , "Class 4_Class 4 %" , "Class 5_Class 5 %", "Green areas_% Green" , "waterbodies_% land use")THEN 'Class 3'

when "Class 4_Class 4 %" = max ("Class 1_Class 1 %" , "Class 2_Class 2 %" , "Class 3_Class 3 %" , "Class 4_Class 4 %" , "Class 5_Class 5 %", "Green areas_% Green" , "waterbodies_% land use")THEN 'Class 4'

when "Class 5_Class 5 %" = max ("Class 1_Class 1 %" , "Class 2_Class 2 %" , "Class 3_Class 3 %" , "Class 4_Class 4 %" , "Class 5_Class 5 %", "Green areas_% Green" , "waterbodies_% land use")THEN 'Class 5'

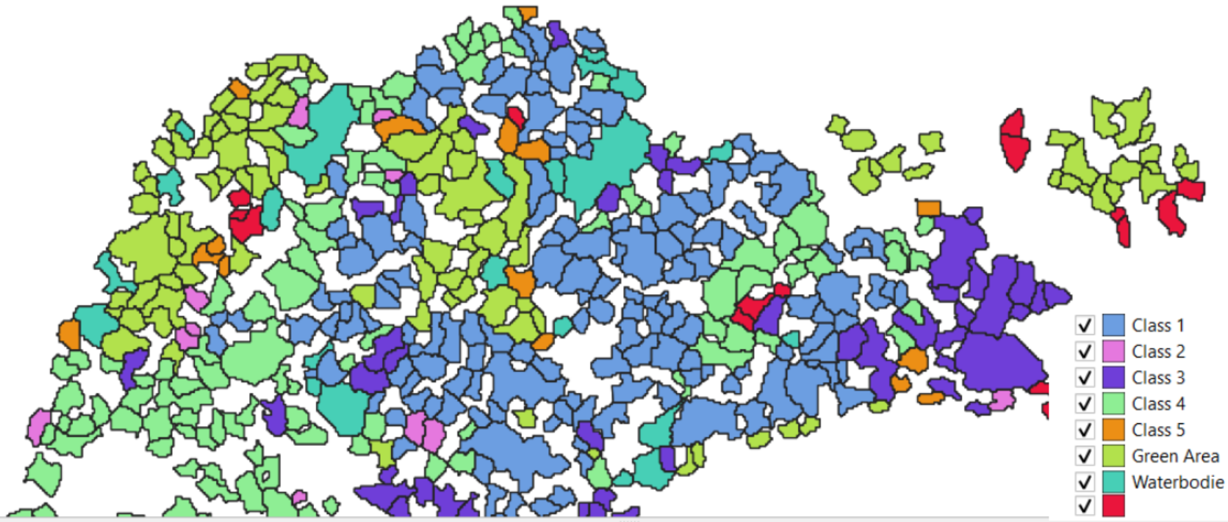
when "Green areas_% Green" = max ("Class 1_Class 1 %" , "Class 2_Class 2 %" , "Class 3_Class 3 %" , "Class 4_Class 4 %" , "Class 5_Class 5 %", "Green areas_% Green" , "waterbodies_% land use")THEN 'Green Areas'

when "waterbodies_% land use" = max ("Class 1_Class 1 %" , "Class 2_Class 2 %" , "Class 3_Class 3 %" , "Class 4_Class 4 %" , "Class 5_Class 5 %", "Green areas_% Green" , "waterbodies_% land use")THEN 'Waterbodies'
end

	ID	VALUE	NAME	DB area	Class 1_Class 1 %	Class 2_Class 2 %	Class 3_Class 3 %	Class 4_Class 4 %	Class 5_Class 5 %	een areas_% Gre	waterbodies_% land use	MAX	MAX Class
1	0	1	1	454407.911	NULL	NULL	NULL	NULL	NULL	70.389	NULL	70.389	Green Area
2	1	2	2	583012.583	NULL	NULL	NULL	NULL	NULL	42.748	NULL	42.748	Green Area
3	2	3	3	505847.983	NULL	NULL	NULL	NULL	NULL	15.783	NULL	15.783	Green Area
4	3	4	4	2580793.542	NULL	87.838	NULL	NULL	NULL	NULL	NULL	87.838	Class 2
5	4	5	5	445857.636	NULL	NULL	NULL	29.464	NULL	NULL	NULL	29.464	Class 4

Result: “MAX class” column is added in the attribute table, showing the maximum landuse% in terms of the name of class in each DB grid (ID).

- Create map based on the “MAX Class” column, categorised.



FINAL Landuse mapped to DB — Features Total: 478, Filtered: 478, Selected: 0

	ID	DB area	Class 1_Cl	Class 2_Cl	Class 3_Cl	Class 4_Cl	Class 5_Cl	Green area	waterbodie	MAX	MAX Class
34	33	1028754.685	NULL	NULL	23.478	66.963	NULL	NULL	0.649	66.963	Class 4
35	34	1680605.183	0.707	NULL	5.352	2.454	NULL	NULL	NULL	5.352	Class 3
36	35	1148822.527	NULL	NULL	8.461	89.464	NULL	NULL	NULL	89.464	Class 4
37	36	368702.583	7.955	NULL	11.977	8.085	NULL	1.584	NULL	11.977	Class 3
38	37	1680444.345	NULL	3.259	6.237	90.420	NULL	NULL	0.019	90.420	Class 4

Result: This mapping shows the Class with the largest %landuse area in each DB Grid.

2.2 Population Density mapped to DB grid

Calculate area of each Subzone with sum of population data.

Intersect Subzone with Flood Basin.

Import Basin shp file and Intersected Subzone shp file into R

```
basin_pop <- read_sf('~/School/AR5805 Advanced Architecture
Studio/QGIS/Data/Flood/Watershed/basin_pop.gpkg')
```

```
basin <- read_sf('~/School/AR5805 Advanced Architecture
Studio/QGIS/Data/Flood/Watershed/Drainage basins.shp')
basin %>%
  select(ID)->basin
```

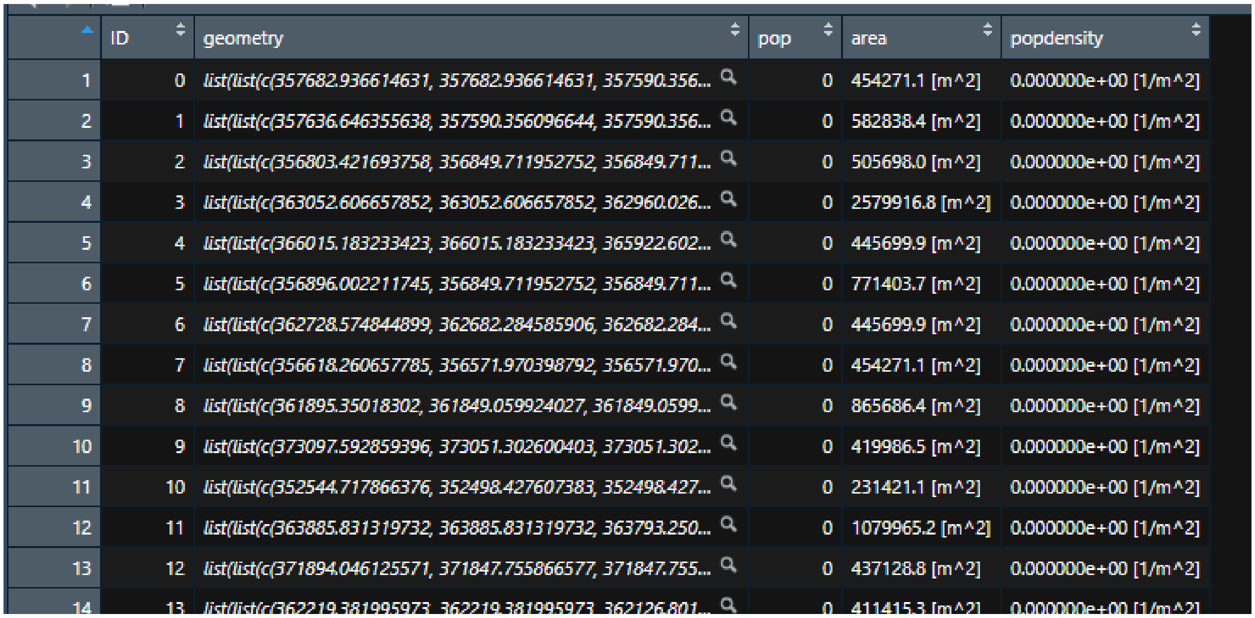
Get area of each intersected subzone

```
basin_pop$subarea <- st_area(basin_pop)
```

	SUBZONE_N	sum	area	ID	geom	subarea
1	MARINA EAST	0	1844040.69	50	list(list(c(103.873912957697, 103.873750424758, 103.873699...	9.571887e+05 [m^2]
2	MARINA EAST	0	1844040.69	59	list(list(c(103.878070472222, 103.878300198217, 103.878641...	6.614617e+04 [m^2]
3	MARINA EAST	0	1844040.69	65	list(list(c(103.870579028478, 103.870927785974, 103.871615...	5.274576e+05 [m^2]
4	INSTITUTION HILL	3170	392563.33	60	list(list(c(103.841970896854, 103.841956303955, 103.841826...	1.452546e+05 [m^2]
5	INSTITUTION HILL	3170	392563.33	67	list(list(c(103.841457446543, 103.841511019433, 103.841578...	6.630966e+03 [m^2]
6	INSTITUTION HILL	3170	392563.33	73	list(list(c(103.838129170118, 103.838250858742, 103.838396...	2.852973e+04 [m^2]
7	ROBERTSON QUAY	3160	506588.95	60	list(list(c(103.837270064538, 103.837303947539, 103.837314...	1.720146e+05 [m^2]
8	ROBERTSON QUAY	3160	506588.95	63	list(list(c(103.834803670973, 103.834776572417, 103.834642...	1.215720e+04 [m^2]
9	ROBERTSON QUAY	3160	506588.95	67	list(list(c(103.841970896854, 103.84214056639, 103.8421507...	1.257905e+04 [m^2]
10	JURONG ISLAND AND BUKOM	0	36639175.34	10	list(list(c(103.678031266486, 103.677447253519, 103.675744...	1.157021e+05 [m^2]
11	JURONG ISLAND AND BUKOM	0	36639175.34	11	list(list(c(103.767437879141, 103.76820462439, 103.7681775...	4.512526e+05 [m^2]
12	JURONG ISLAND AND BUKOM	0	36639175.34	13	list(list(c(103.762447952813, 103.762206919628, 103.761726...	1.253092e+05 [m^2]
13	JURONG ISLAND AND BUKOM	0	36639175.34	16	list(list(c(103.755790908279, 103.755774340546, 103.755773...	5.146078e+05 [m^2]
14	JURONG ISLAND AND BUKOM	0	36639175.34	17	list(list(c(103.758909117943, 103.758912564473, 103.758940...	3.712757e+05 [m^2]
15	JURONG ISLAND AND BUKOM	0	36639175.34	18	list(list(c(103.758154543649, 103.758242672235, 103.758864...	4.038492e+05 [m^2]
16	JURONG ISLAND AND BUKOM	0	36639175.34	20	list(list(c(103.664679279671, 103.664263296462, 103.664262...	1.377889e+06 [m^2]
17	JURONG ISLAND AND BUKOM	0	36639175.34	22	list(list(c(103.698787252791, 103.698371262918, 103.698370...	6.372893e+05 [m^2]
18	JURONG ISLAND AND BUKOM	0	36639175.34	23	list(list(c(103.717502641007, 103.717445122146, 103.717415...	4.987310e+05 [m^2]

Calculate population of each intersected subzone by its proportion of the subzone * pop, and sum each row with the same ID together to get the population of each flood basin.

```
basin_pop%>%
  mutate(pop=as.integer(sum*subarea/area))%>%
  group_by(ID)%>%
  summarise(pop=sum(pop))->basinpop
```



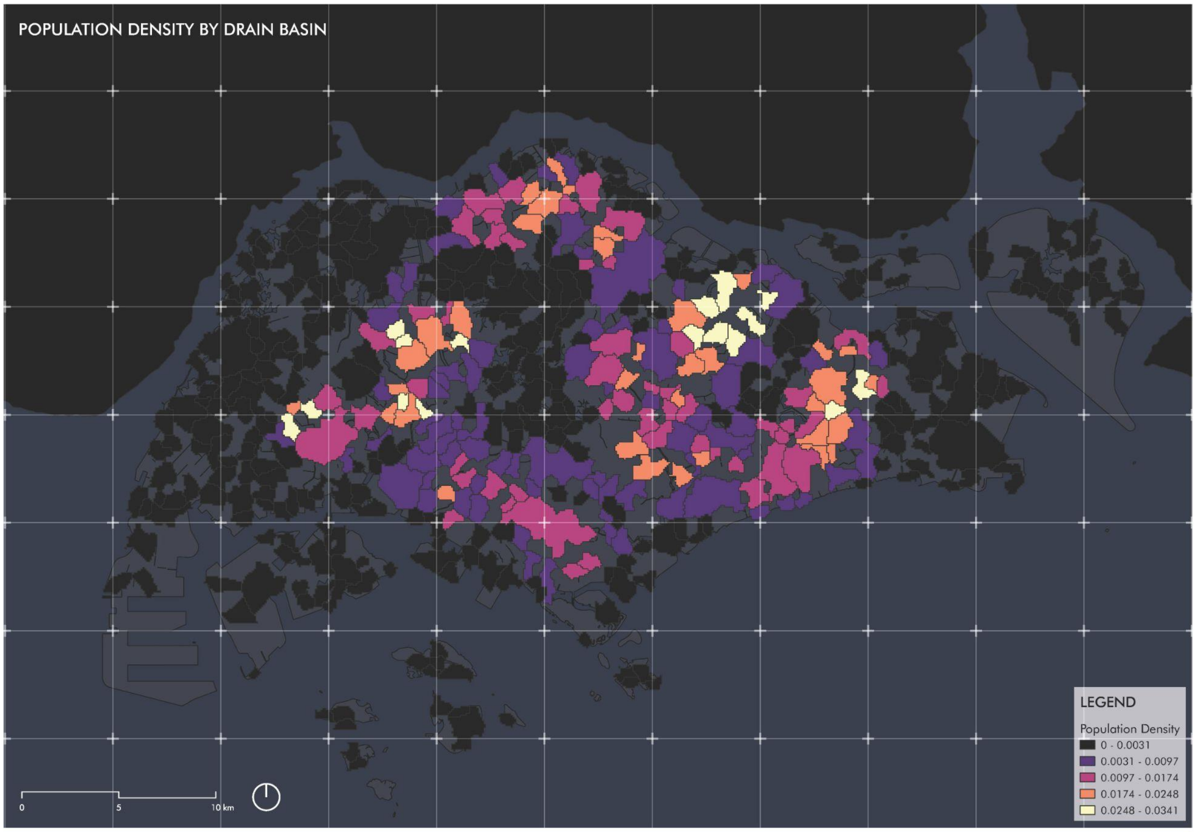
	ID	geometry	pop	area	popdensity
1	0	list(list(c(357682.936614631, 357682.936614631, 357590.356...	0	454271.1 [m^2]	0.000000e+00 [1/m^2]
2	1	list(list(c(357636.646355638, 357590.356096644, 357590.356...	0	582838.4 [m^2]	0.000000e+00 [1/m^2]
3	2	list(list(c(356803.421693758, 356849.711952752, 356849.711...	0	505698.0 [m^2]	0.000000e+00 [1/m^2]
4	3	list(list(c(363052.606657852, 363052.606657852, 362960.026...	0	2579916.8 [m^2]	0.000000e+00 [1/m^2]
5	4	list(list(c(366015.183233423, 366015.183233423, 365922.602...	0	445699.9 [m^2]	0.000000e+00 [1/m^2]
6	5	list(list(c(356896.002211745, 356849.711952752, 356849.711...	0	771403.7 [m^2]	0.000000e+00 [1/m^2]
7	6	list(list(c(362728.574844899, 362682.284585906, 362682.284...	0	445699.9 [m^2]	0.000000e+00 [1/m^2]
8	7	list(list(c(356618.260657785, 356571.970398792, 356571.970...	0	454271.1 [m^2]	0.000000e+00 [1/m^2]
9	8	list(list(c(361895.35018302, 361849.059924027, 361849.0599...	0	865686.4 [m^2]	0.000000e+00 [1/m^2]
10	9	list(list(c(373097.592859396, 373051.302600403, 373051.302...	0	419986.5 [m^2]	0.000000e+00 [1/m^2]
11	10	list(list(c(352544.717866376, 352498.427607383, 352498.427...	0	231421.1 [m^2]	0.000000e+00 [1/m^2]
12	11	list(list(c(363885.831319732, 363885.831319732, 363793.250...	0	1079965.2 [m^2]	0.000000e+00 [1/m^2]
13	12	list(list(c(371894.046125571, 371847.755866577, 371847.755...	0	437128.8 [m^2]	0.000000e+00 [1/m^2]
14	13	list(list(c(362219.381995973, 362219.381995973, 362126.801...	0	411415.3 [m^2]	0.000000e+00 [1/m^2]

Calculate density of each flood basin by dividing pop with area of flood basin.

```
as.data.frame(basinpop)%>%
  select(ID,pop)->basinpop
```

```
left_join(basin,basinpop,by="ID") -> basinpop
```

```
basinpop$area <- st_area(basinpop)
basinpop%>%
  mutate(popdensity=pop/area)->basinpop
```

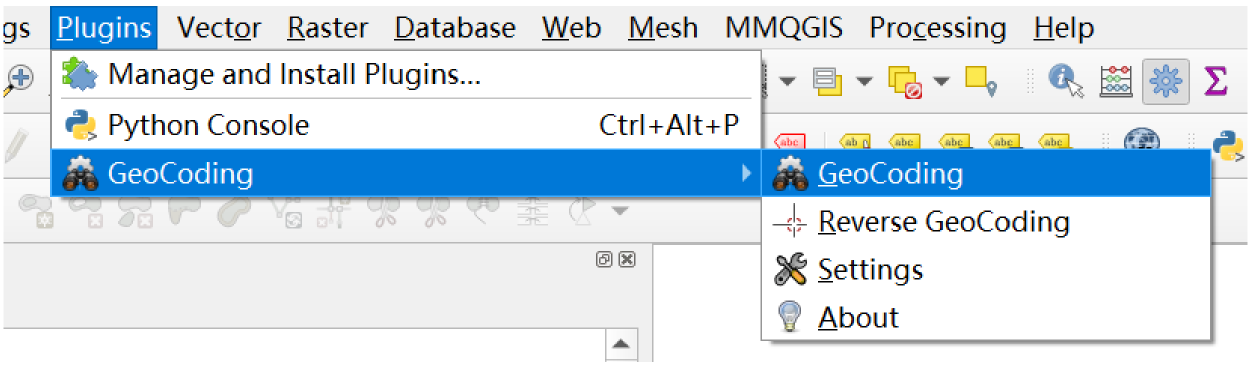


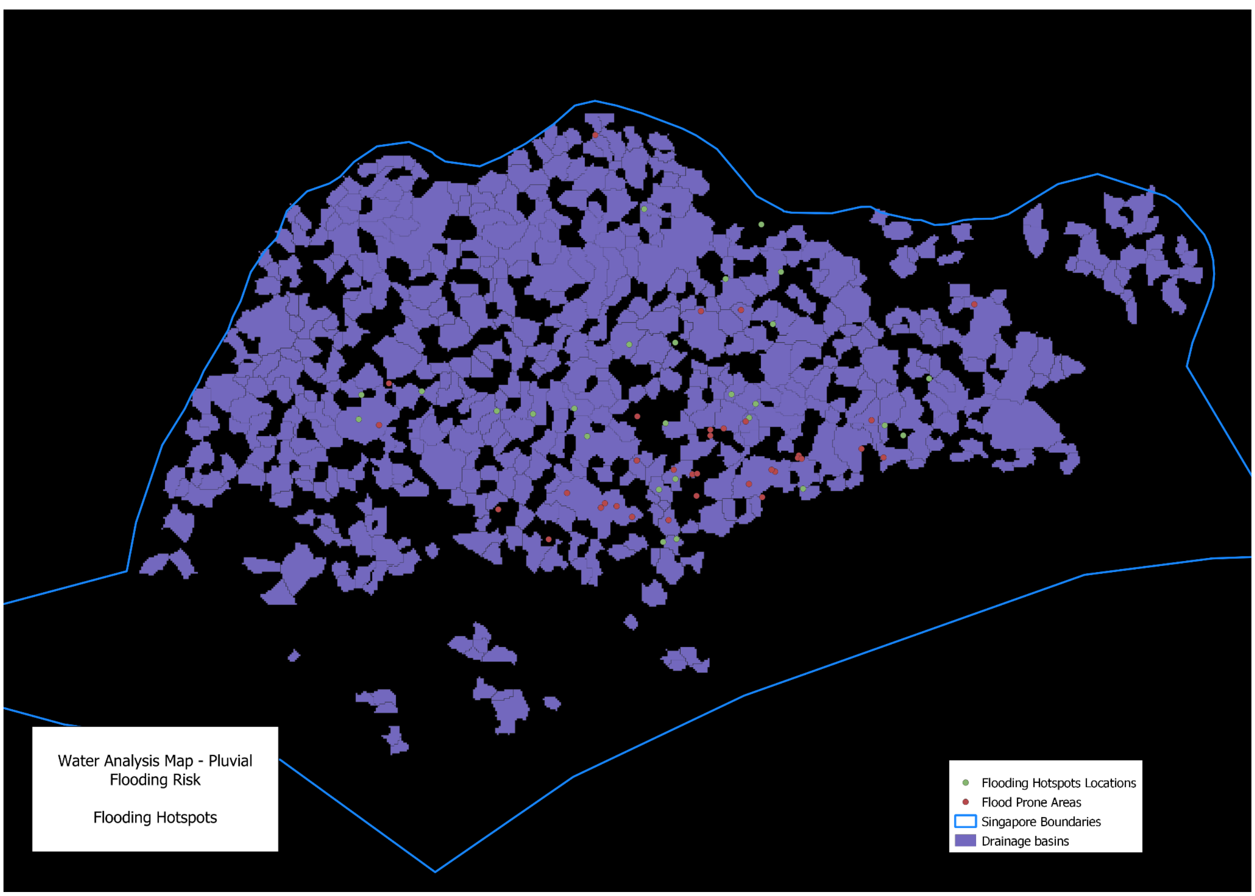
POPULATION DENSITY BY DRAIN BASIN
LEGEND
Population Density
0 - 0.0031
0.0031 - 0.0097
0.0097 - 0.0174
0.0174 - 0.0248
0.0248 - 0.0341
0
5
10 km

2.3 PUB list of Flood Prone areas and Hotspots mapped to DB grid

1. Use Geocoding plug-in in QGIS to locate the locations of Flood Prone Areas and Hotspots on the drainage basins map

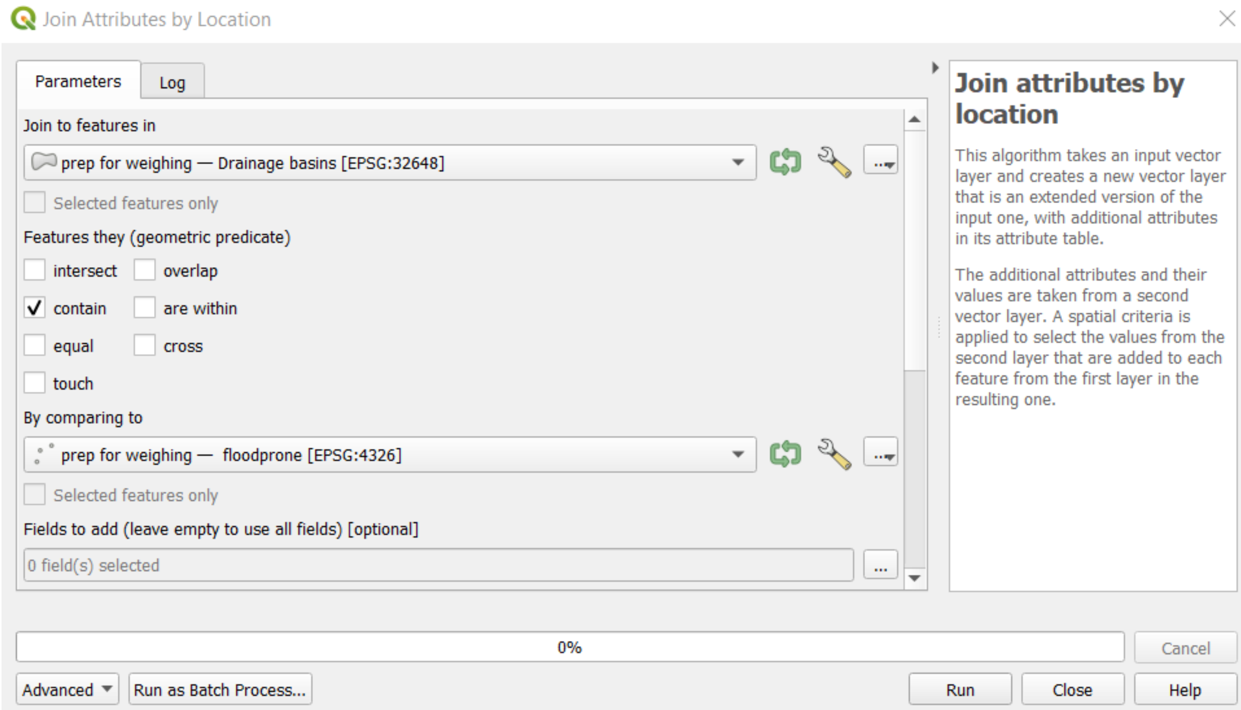
https://guides.library.ucsc.edu/DS/Resources/QGIS#:~:text=To%20use%20it%2C%20select%20the,where%20the%20address%20is%20located

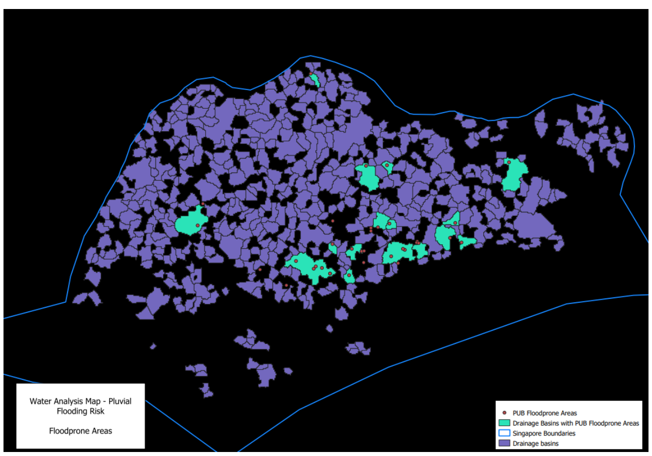


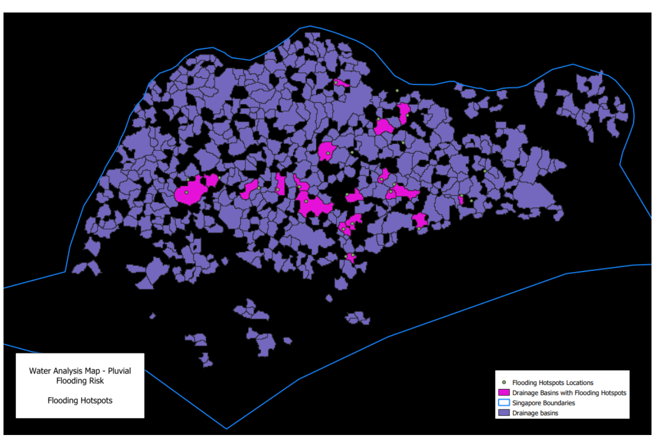


2. Project Flood Prone Areas and Hotspots to Drainage Basins

Vector > Data Management Tools > Join Attributes by Location

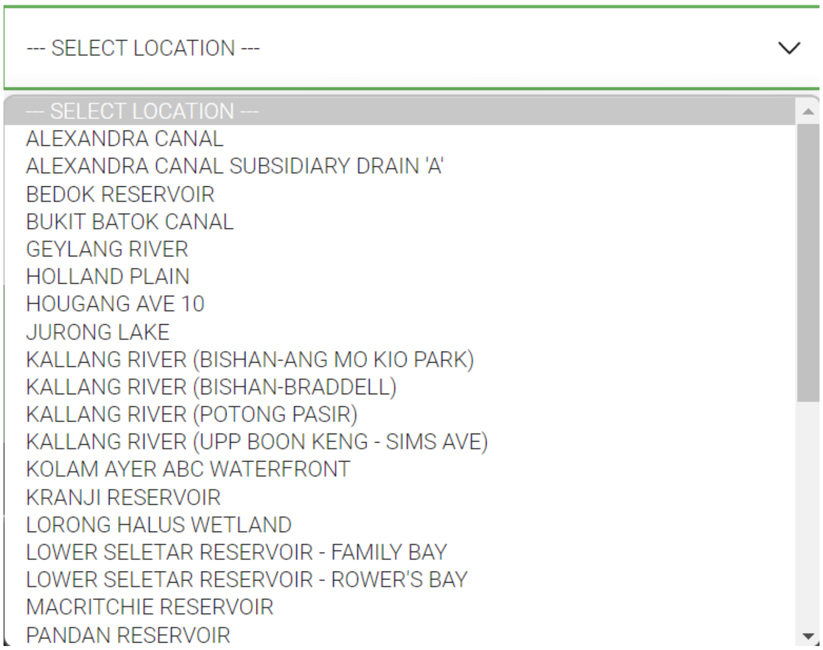




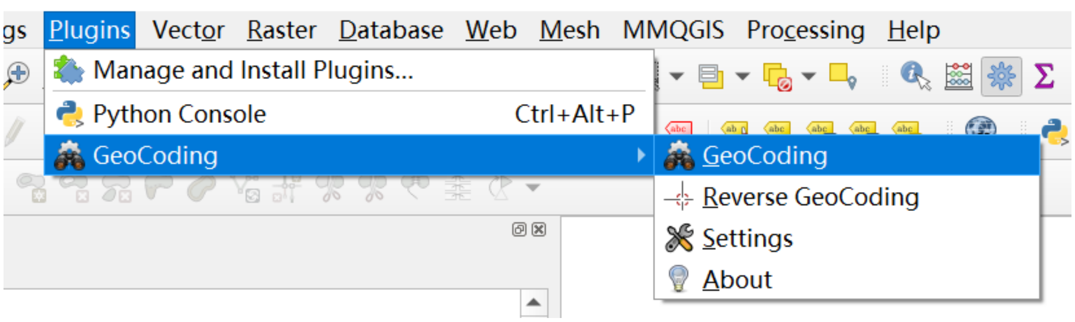


2.4 ABC water management locations and methods mapped to DB grid

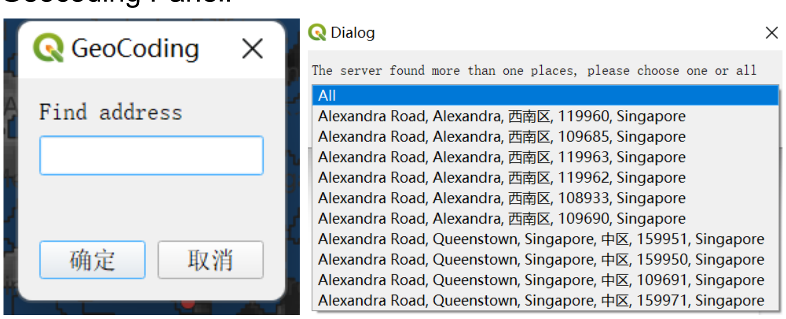
1. Find ABC water locations from PUB website: [ABC Waters Virtual Tour (pub.gov.sg)]()



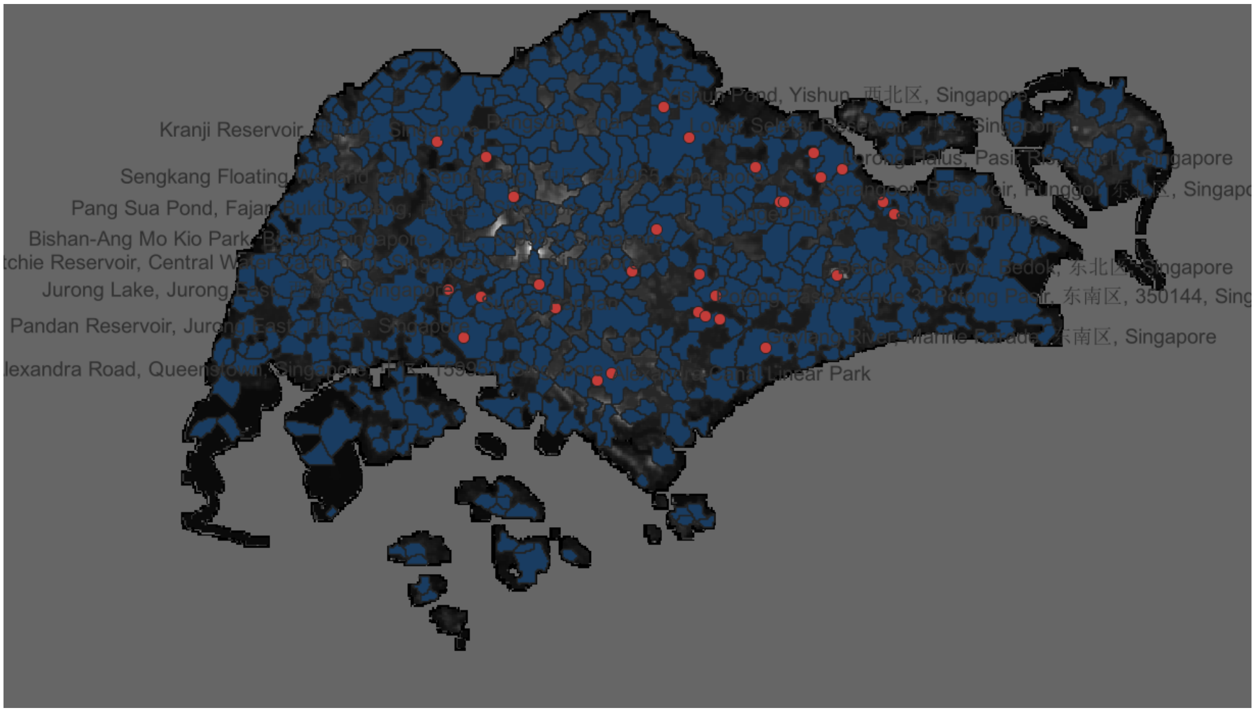
2. Use Geocoding plug-in in QGIS to locate the locations on the drainage basins map.



Geocoding Panel:



The outcome of all the locations on map:



3. Multi-criteria analysis (Weighting System)

Goal: To assess which flood-prone areas pose a higher risk (in terms of damages)

Highest risk >> BLACK

Risk Causative Criterion	Unit	Class	Risk Class Ranges and Ratings	Risk Class Ratings	Weight (%)
Population Density	People/ m2	0	Very Low	1	
		280 - 5000	Low	2	
		5000 - 13000	Moderate	3	
		13000 - 25000	High	4	
		25000 - 45000	Very High	5	
Land Use (excluding parks and waterbodies)	Classification	Class 1[5] (Residential)	Very High	5	
		Class 2[6] (Humanitarian and other Essential Facilities)	High	4	
		Class 3[7] (Transport facilities)	Moderate	3	
		Class 4[8] (Economic facilities)	Low	2	
		Class 5[9] (Social)	Very Low	1	

[5] Residential, Residential with commercial 1st storey, Residential/ Institution
[6] Civic & Community Institution, Health & Medical Care, Utility
[7] Road, Transport Facilities, Rapid Transit, Port/Airport
[8] Commercial & Residential, Commercial, Business Park, Business Park - White, Business 1 (B1), Business 2 (B2), Business 2 - White, Agriculture
[9] Cultural and heritage, Religious (cemetery), Leisure and Entertainment, Hotel

Green areas	% land	0 - 20%	Very High	5	
		20 - 40%	High	4	
		40 - 60%	Moderate	3	
		60 - 80%	Low	2	
		80 - 100%	Very Low	1	
Waterbodies	% land	0 - 20%	Very High	5	
		20 - 40%	High	4	
		40 - 60%	Moderate	3	
		60 - 80%	Low	2	
		80 - 100%	Very Low	1	
PUB ABC Strategies	Relative effectiveness	0 - 20%	Highest	5	
		20 - 40%	Higher	4	
		40 - 60%	Moderate	3	
		60 - 80%	Lower	2	
		80 - 100%	Lowest	1	

3.1 Assessing Percentage Effectiveness of PUB ABC Strategies (Weighting System)

- Locations of ABC
- Types of ABC in each location

Goal: To assess the relative effectiveness of **each** ABC site

Type of strategy	Strategy Effectiveness	Strategy Effectiveness Class Ratings
Parks and reservoir	Very High	5
Canals	High	4
Rain Gardens	Moderate	3
Gravel Swales	Low	2
Vegetated Swales	Very Low	1

*ABC sites that include 'Parks and reservoir' strategy are removed from the assessment as any successive strategies included will have minimal contribution to ABC strategy effectiveness

10% - 5
30% - 4
40% - 3
50% - 2
70% - 7
90% - 1

("Canal" * 4 + "Rain garde" * 3 + "Bioretenti" * 2 + "Gravel Swa") / 2

3.2 Relative Effectiveness of PUB ABC Strategies Map based on Drainage Basin

1. Geotag locations & effectiveness of systems through geocoding plugin, which automatically assigned location

- Research ABC waters projects location https://www.pub.gov.sg/abcwaters/explore
- Research efficiency of different types of ABC strategy

  Before starting the design of a development, it is essential to understand the constraints and potential of the site and factors that would affect stormwater flow:
  • Topography (natural slopes/depressions)
  • Geology (soil type and quality – porosity, infiltration and conveyance properties)
  • Internal drainage, sub-catchments and the connection points to public drains.
  The design of a development is also bound by the basic urban planning parameters such as site coverage, plot ratio, height restrictions and land use.

Next, the calibration of the three ABCs was carried out by adjusting some of the model parameters as described in Section 2.4.1 with the final values indicated as follows.

1. *Vegetative cover [FB21:0.4; FB9:0.2; FB1 and 2: 0.4].*
2. *Porosity in soil layer [FB21:0.45; FB9:0.4; FB1 and 2: 0.45].*
3. *Infiltration capacities of soil layer (mm/hr) [FB21:50; FB9:55; FB1 and 2: 50].*
4. *Leaking capacities in soil layer (mm/hr) [FB21:35; FB9:42; FB1 and 2: 40].*
5. *Infiltration capacity to surrounding soil in storage layer (mm/hr) [FB21:0; FB9:0; FB1 and 2: 0].*
6. *Clogging factor in storage layer [FB21:0; FB9:0; FB1 and 2: 0].*

Table 3. Peak flow reduction performance of the various feature types for the 10-year design storm.

Design Feature Type	Average Peak Flow Reduction (%)	Average Normalised Peak Flow Reduction (%)
Rain gardens *	39%	47%
Gravel swales	9%	25%
Vegetated swales	0%	0%

Note: * Excluding rain gardens without orifice outlets (i.e., rain gardens FB6, FB10, FB15 and FB17).

Table A11. Required treated catchment areas and rain garden sizes to achieve C = 0.55 for the various land use types (percentages in brackets represents the upper limits beyond which the C-value would exceed 0.55 due to deteriorating performance of the rain garden).

Land Use Type	Rain Garden Area (% of Total Site Area)						
	4%	5%	6%	7%	8%	9%	10%
Residential (C = 0.88)	N.A.	N.A.	45.2% (56.4%)	42.4% (74.4%)	41.6% (87.8%)	41.5% (87.8%)	41.3% (87.8%)
Mixed residential–commercial (C = 0.925)	N.A.	N.A.	45.8% (55.0%)	43.3% (72.2%)	41.9% (87.4%)	41.8% (87.4%)	41.4% (87.4%)
Commercial (C = 0.97)	N.A.	N.A.	47.2% (55.0%)	43.9% (72.1%)	43.3% (85.5%)	42.8% (85.5%)	41.8% (85.5%)

Table 2. Outflow and effective C-value results of the precinct and alternative scenarios for the 10-year design storm.

S/N	Label	Scenario	Qmax (m^3/s)	Reduction * in Qmax	Effective C-Value
1	No treatment/detention	Precinct without any treatment or detention	2.13	0%	0.89
2	Orifice only	Precinct with orifice outlets only	2.13	0%	0.89
3	Typical ABC	Precinct with typical design of ABC Waters features implemented in Singapore	1.85	13.0%	0.77
4	ABC + Orifice	Precinct with ABC Waters features and orifice outlets but without gravel storage	1.86	12.6%	0.77
5	ABC + Storage	Precinct with ABC Waters features and gravel storage but without orifice outlets	1.75	17.7%	0.73
6	ABC + Storage + Orifice	Precinct with ABC Waters features coupled with gravel storage and orifice outlet	1.44	32.6%	0.60

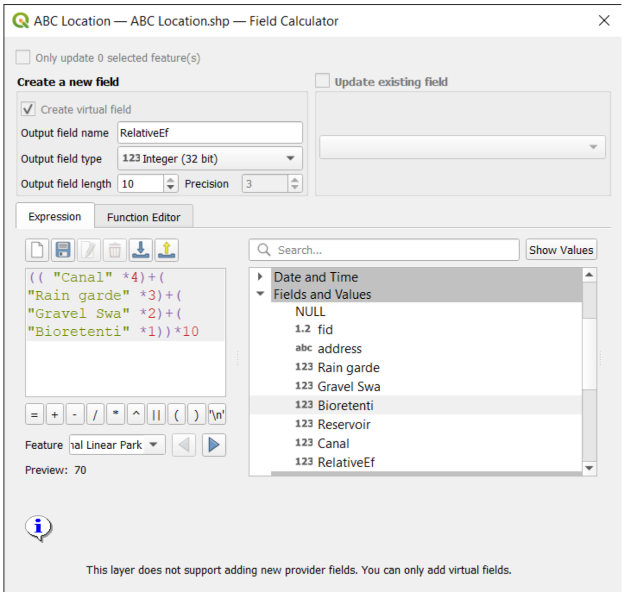
Note: * Relative to Scenario 1 of the precinct without any treatment or detention.

- Ranking was assigned over assigning real values, multiple variables needed to fully access effectiveness. Ranking also considers the number of strategies used in a single ABC water zone. Derived relative effectiveness is logical but requires the removal of jarring anomaly - reservoirs/ park which have extremely high efficiency for drainage (does not support our ranking too)

		Parks and Reservoirs (5)	Canal (4)	Rain Gardens (3)	Gravel Swales (2)	Bioretention/ vegetated swales (1)		Cumulative Ratings	Relative Effectiveness
Alexandra Road	Wetlands/ Canal		Y			Y		5	50.00%
Alexandra Canal Subsic	Rain Gardens/ Canal		Y	Y				7	70.00%
Bedok Reservoir	Reservoir	Y						-	
Bukit Timah Canal	Rain Gardens/ Canal		Y	Y				7	70.00%
Geylang River	Rain Gardens		Y	Y				7	70.00%
Holland Plain/Bukit Timah First Diversion Canal	Rain Garden/ Wetland			Y		Y		4	40.00%
Hougang Avenue 10	Rain Gardens/ Canal		Y	Y				7	70.00%
Jurong Lake	Wetlands	Y				Y		-	
Bishan AMK Park	soil bio-engineering/ cleansing biotope/ vegetated swales	Y			Y	Y		-	

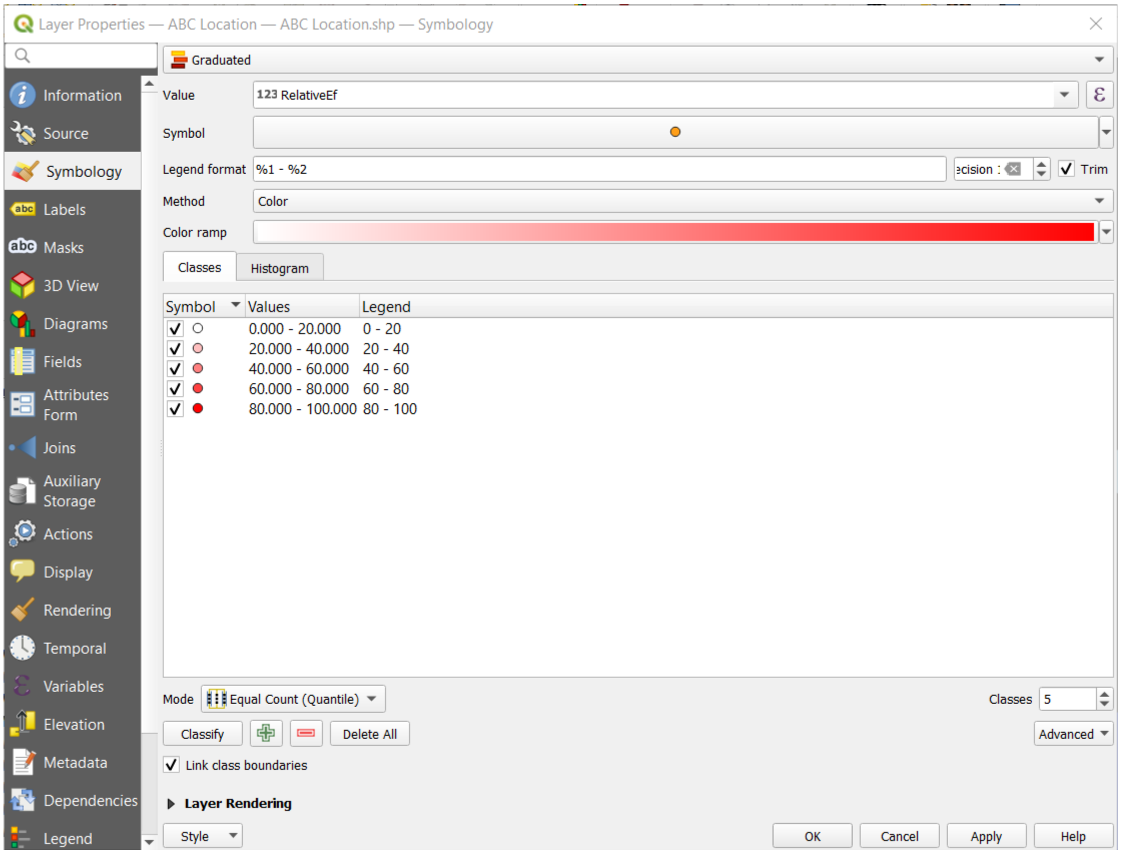
- Utilize geocoding plugin to tag locations on the map https://guides.library.ucsc.edu/DS/Resources/QGIS#:~:text=To%20use%20it%2C%20select%20the,where%20the%20address%20is%20located

2. Assign Relative Effectiveness of each ABC site as an attribute



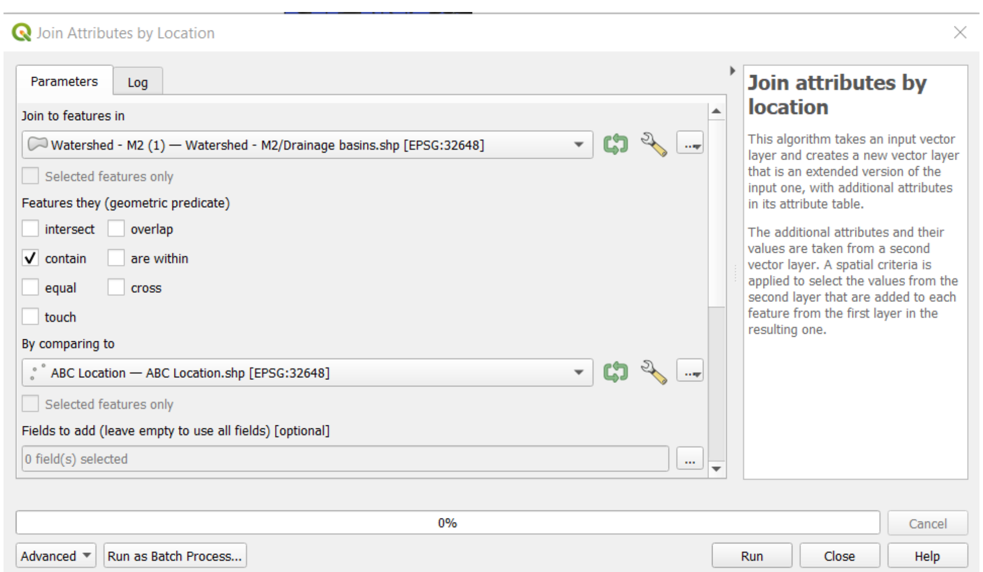
	fid	address	Rain garde	Gravel Swa	Bioretenti	Reservoir	Canal	RelativeEf
1	1	Alexandra Roa...	0	0	1	0	1	50
2	2	Bedok Reservo...	0	0	0	1	0	0
3	3	Bukit Timah C...	1	0	0	0	1	70
4	4	Geylang River,...	1	0	0	0	1	70
5	5	Holland Plain, ...	1	0	1	0	0	40
6	6	Hougang Ave...	1	0	0	0	1	70
7	7	Jurong Lake, J...	0	0	1	1	0	10
8	8	Bishan-Ang M...	0	1	1	1	0	30
9	9	Braddell Road,...	1	0	0	0	1	70
10	10	Potong Pasir A...	1	0	1	0	0	40
11	11	Upp Boon Ken...	1	0	0	0	1	70
12	12	Kranji Reservoi...	0	0	0	1	0	0
13	13	Lorong Halus, ...	0	0	1	0	0	10
14	14	Lower Seletar ...	0	0	0	1	0	0
15	15	MacRitchie Re...	0	0	0	1	0	0
16	16	Pandan Reserv...	0	0	0	1	0	0
17	17	Pangsua Canal	0	0	0	0	1	40
18	18	Pang Sua Pon...	0	0	1	0	0	10
19	19	Rocher Canal	1	0	0	0	1	70
20	20	Sengkang Floa...	0	0	1	0	0	10
21	21	Serangoon Re...	0	0	0	1	0	0
22	22	Sungei Api Api	1	1	0	0	0	50
23	23	Sungei Pandan	1	0	0	0	0	30
24	24	Sungei Pinang	1	1	0	0	1	90
25	25	Sungei Tampi...	1	0	0	0	0	30
26	26	Whampoa Kim...	1	0	0	0	0	30
27	27	Sungei Wham...	1	0	0	0	0	30
28	28	Yishun Pond, Y...	0	0	1	0	0	10
29	29	Alexandra Can...	1	0	0	0	1	70

3. Assign classes based on Relative Effectiveness value



4. Project classes to Drainage Basin grid

Vector > Data Management Tools > Join Attributes by Location

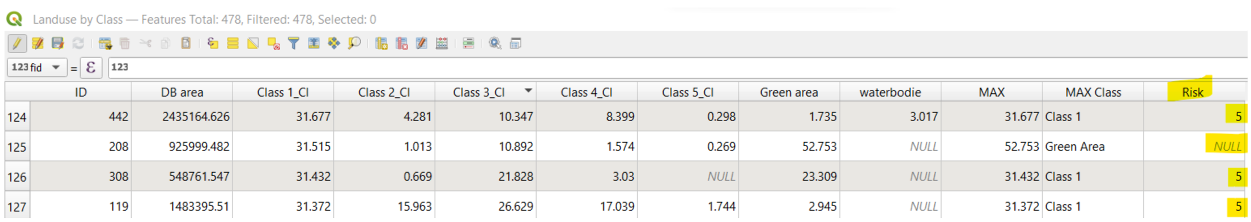


4. Weighing overlay in raster calculator

1. Reclassify values in (3) Multi-criteria analysis to each DB (ID) for “Landuse by class”

In “Landuse by class” >> Field calculator, create a new field “ Risk ” , Query:

```
case
WHEN "MAX Class" = 'Class 1' THEN 5
WHEN "MAX Class" = 'Class 2' THEN 4
WHEN "MAX Class" = 'Class 3' THEN 3
WHEN "MAX Class" = 'Class 4' THEN 2
WHEN "MAX Class" = 'Class 5' THEN 1
END
```



	ID	DB area	Class 1_CI	Class 2_CI	Class 3_CI	Class 4_CI	Class 5_CI	Green area	waterbodie	MAX	MAX Class	Risk
124	442	2435164.626	31.677	4.281	10.347	8.399	0.298	1.735	3.017	31.677	Class 1	5
125	208	925999.482	31.515	1.013	10.892	1.574	0.269	52.753	NULL	52.753	Green Area	NULL
126	308	548761.547	31.432	0.669	21.828	3.03	NULL	23.309	NULL	31.432	Class 1	5
127	119	1483395.51	31.372	15.963	26.629	17.039	1.744	2.945	NULL	31.372	Class 1	5

Result: “Risk” column is added in the attribute table, showing the allocated risk score (1-5) in each DB grid (ID).

- Rasterize (Vector to Raster)

Result: raster map generated for landuse by class

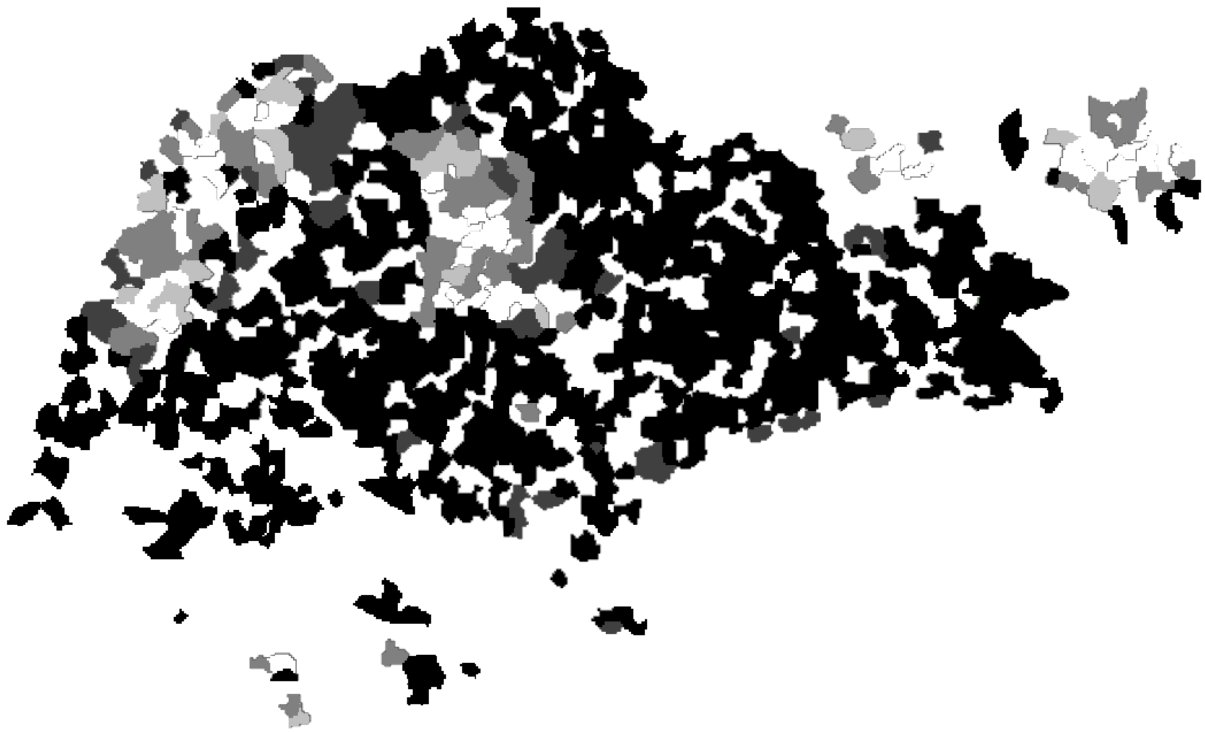
2. Reclassify values in (3) Multi-criteria analysis to each DB (ID) for “Green areas”

In “Green areas” >> Field calculator, create a new field “ Risk ” , Query:

```
case
WHEN "Green area" < 20 THEN 5
WHEN "Green area"  >= 20 AND "Green area" < 40 THEN 4
WHEN "Green area"  >= 40 AND "Green area" < 60 THEN 3
WHEN "Green area"  >= 60 AND "Green area" < 80 THEN 2
WHEN "Green area"  >= 80 AND "Green area" <= 100 THEN 1
ELSE 5
END
```

	ID	DB area	Class 1_Cl	Class 2_Cl	Class 3_Cl	Class 4_Cl	Class 5_Cl	Green area	waterbodie	MAX	MAX Class	risk
1	0	454407.911	NULL	NULL	NULL	NULL	NULL	70.389	NULL	70.389	Green Area	2
2	1	583012.583	NULL	NULL	NULL	NULL	NULL	42.748	NULL	42.748	Green Area	3
3	2	505847.983	NULL	NULL	NULL	NULL	NULL	15.783	NULL	15.783	Green Area	5
4	3	2580793.542	NULL	87.838	NULL	NULL	NULL	NULL	NULL	87.838	Class 2	5
5	4	445857.636	NULL	NULL	NULL	29.464	NULL	NULL	NULL	29.464	Class 4	5

Result: “Risk” column is added in the attribute table, showing the allocated risk score (1-5) in each DB grid (ID), with “Green area” NULL (0%) returning a score of 5.



Result: raster map generated for green areas

3. Reclassify values in (3) Multi-criteria analysis to each DB (ID) for “Waterbodies”

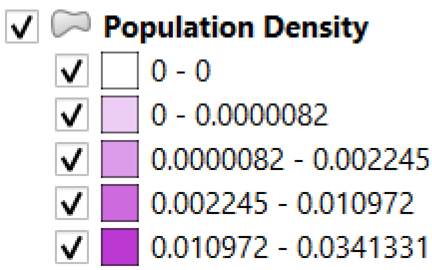
In “Waterbodies” >> Field calculator, create a new field “ Risk ” , Query:

```
case
WHEN  "waterbodie"  < 20 THEN 5
WHEN  "waterbodie"   >= 20 AND "waterbodie" < 40 THEN 4
WHEN  "waterbodie"   >= 40 AND "waterbodie" < 60 THEN 3
WHEN  "waterbodie"   >= 60 AND "waterbodie" < 80 THEN 2
WHEN  "waterbodie"   >= 80 AND "waterbodie" <= 100 THEN 1
ELSE 5
END
```

	ID	DB area	Class 1_CI	Class 2_CI	Class 3_CI	Class 4_CI	Class 5_CI	Green area	waterbodie	MAX	MAX Class	risk
1	0	454407.911	NULL	NULL	NULL	NULL	NULL	70.389	NULL	70.389	Green Area	2
2	1	583012.583	NULL	NULL	NULL	NULL	NULL	42.748	NULL	42.748	Green Area	3
3	2	505847.983	NULL	NULL	NULL	NULL	NULL	15.783	NULL	15.783	Green Area	5
4	3	2580793.542	NULL	87.838	NULL	NULL	NULL	NULL	NULL	87.838	Class 2	5
5	4	445857.636	NULL	NULL	NULL	29.464	NULL	NULL	NULL	29.464	Class 4	5

Result: “Risk” column is added in the attribute table, showing the allocated risk score (1-5) in each DB grid (ID), with “Waterbodie” NULL (0%) returning a score of 5.

4. Reclassify values in (3) Multi-criteria analysis to each DB (ID) for “Population Density”

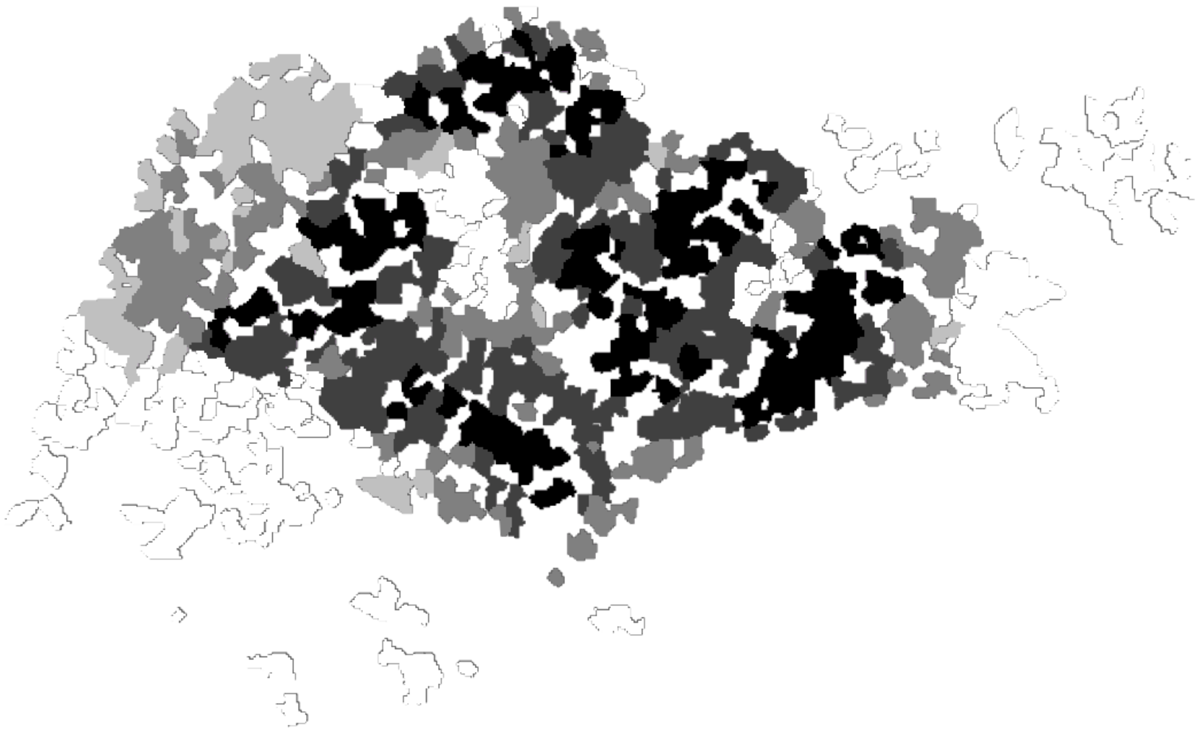


In “Population Density” >> Field calculator, create a new field “ Risk ” , Query:

```
case
WHEN "popdensity" = 0 THEN 1
WHEN "popdensity" >0 AND "popdensity" <0.0000082 THEN 2
WHEN "popdensity" >= 0.0000082 AND "popdensity" < 0.002245 THEN 3
WHEN "popdensity" >= 0.002245 AND "popdensity" < 0.010972 THEN 4
WHEN "popdensity" >=0.010972 THEN 5
END
```

	fid	ID	pop	area	popdensity	Risk
94	107	106	16790	1482809.34974...	0.011323100979159345	5
95	124	123	34442	3128470.59339...	0.011009213279083814	5
96	88	87	4332	394273.006290...	0.010987310647406297	5
97	134	133	6100	557124.900193...	0.010949070841899023	4

Result: “Risk” column is added in the attribute table, showing the allocated risk score (1-5) in each DB grid (ID)



5. Reclassify values in (3) Multi-criteria analysis to each DB (ID) for “ABC strategies effectiveness”

In “ABC strategies effectiveness” >> Field calculator, create a new field “ Risk ” , Query:
WHEN "RelativeEf" < 20 THEN 5
WHEN "RelativeEf" >= 20 AND "RelativeEf" < 40 THEN 4
WHEN "RelativeEf" >= 40 AND "RelativeEf" < 60 THEN 3
WHEN "RelativeEf" >= 60 AND "RelativeEf" < 80 THEN 2
WHEN "RelativeEf" >= 80 AND "RelativeEf" <= 100 THEN 1
END

		address	Rain garde	Gravel Swa	Bioretenti	Reservoir	Canal	RelativeEf	Risk
1	2	Bedok Reservoi...	0	0	0	1	0	100	1
2	12	Kranji Reservoir,...	0	0	0	1	0	100	1
3	14	Lower Seletar R...	0	0	0	1	0	100	1
4	15	MacRitchie Res...	0	0	0	1	0	100	1
5	16	Pandan Reservo...	0	0	0	1	0	100	1
6	20	Serangoon Res...	0	0	0	1	0	100	1
7	23	Sungei Pinang	1	1	0	0	1	90	1
8	3	Bukit Timah Ca...	1	0	0	0	1	70	2
9	4	Geylang River, ...	1	0	0	0	1	70	2
10	6	Hougang Aven...	1	0	0	0	1	70	2
11	9	Braddell Road, ...	1	0	0	0	1	70	2

Result: “Risk” column is added in the attribute table, showing the allocated risk score (1-5) in each DB grid (ID)

4.2 Weighing in attribute table

Method 2 - Field calculator

Assign 0 to NULL values

- Green and Water areas
- Set Green area to a % out of 5 >> % out of 5
 ("Green area" / 100) * 5 ❌

** needs to be inverted

- Population Density

- In “Population Density” >> Field calculator, create a new field “Risk % out of 5” , Real No.
Query:
 ("popdensity" / maximum("popdensity"))* 5

✔️

- Landuse by class% (Humanitarian Damages)

- In “Landuse by class” >> Field calculator, create a new field “Risk % out of 5” , Real No.
Query:
(("Class 1_Cl" * 5) +
("Class 2_Cl" * 4) +

("Class 3_CI" * 3) +
("Class 4_CI" * 2) +
("Class 5_CI" * 1)) / 5 ❌

(("Class 1_CI"/100 * 5) +
("Class 2_CI"/100 * 4) +
("Class 3_CI"/100 * 3) +
("Class 4_CI"/100 * 2) +
("Class 5_CI"/100 * 1)) / 5 ❌

(("Class 1_CI"/100 * 5) +
("Class 2_CI"/100 * 4) +
("Class 3_CI"/100 * 3) +
("Class 4_CI"/100 * 2) +
("Class 5_CI"/100 * 1)) ✔️

Calculate values in (3) Multi-criteria analysis to each DB (ID) for “ABC strategies effectiveness”

In “ABC strategies effectiveness” >> Field calculator, create a new field “Final @ 1 ” , real no. , Query:

("ABC risk_Risk" + "Green area %_risk" + "Water Body %_Risk" + " Landuse by Class_Risk " + "Population Density_Risk") / 5

- Calculate Final values

In “Joined risk - 09082022” >> Field calculator, create a new field “Final @ 1 ” , real no. , Query:

" Landuse by Class_Risk % out of 5" - ("Green area %_risk"+"Water Body %_Risk") - "ABC risk_Risk" + "Hotspots_Risk" + "floodprone_Risk" + Popdens (resi) + surface area

joined risk - 09082022 — Features Total: 478, Filtered: 478, Selected: 0

	fid	ID	Landuse by Class_MAX Class	anduse by Class_Risk % out of	een area %_ri	ter Body %_R	ABC risk_Risk	Population Density_Risk % out of 5	Hotspots_Risk	floodprone_Risk	Final @ 1	Final @ 2	Final
1	107	106	Class 1	4.2083	5	5	0	1.6586687025122882	5	5	14.208	10.000	24.208
2	120	119	Class 1	3.36421	5	5	0	1.1885314568150949	5	5	13.364	10.000	23.364
3	155	154	Class 4	2.6955599999999995	5	5	0	1.4656045206692072	5	5	12.696	10.000	22.696
4	163	162	Class 1	3.5196199999999997	5	5	0	2.1636587366694386	5	5	13.520	10.000	23.520
5	59	58	Class 4	2.04355	5	5	0	0.8542605982369007	0	5	12.044	5.000	17.044
6	64	63	Class 1	3.80493	5	5	2	1.9645997867430245	0	5	13.805	3.000	16.805


3.9644899999999996
5
5
0
2.6059145598725513
Uh-oh!
QGIS ended unexpectedly
Oh dear! Something unexpected happened and QGIS ended without being able to handle the error gracefully.
Are you keen to help us fix bugs? QGIS relies on donations to pay developers to do funded bug fixing to improve the stability of the software. We also have a team of enthusiastic volunteers who are all working hard to improve the quality of QGIS. To do that, we need your help. Find out how to help our developers.
Send us a helpful bug report by using the 'Copy Report' button below, then open a ticket on the QGIS Issue Tracker.
Copy Report
Tell us something about what you were doing when QGIS crashed.
Please include as much information as you can, as well as any steps we can follow to reproduce the issue, if possible.
Tell us something about when you got the crash
Report details
Python Stack Trace
Windows fatal exception: access violation
Current thread 0x0000ae7c (most recent call firs
Stack Trace
No stack trace is available.
QGIS Info
QGIS Version: 3.26.2-Buenos Aires
QGIS code revision: feec3d3b12f
Compiled against Qt: 5.15.3
Reload QGIS
Quit
4.38845
5
Preview: 7
Geometry