

Spatial Database Development & Applications



ISTANBUL **TECHNICAL** UNIVERSITY
Sp. Anly. and Alg. in GIS
Week 4

Res. Assist. Ömer AKIN & Res. Assist. Doğuş GÜLER

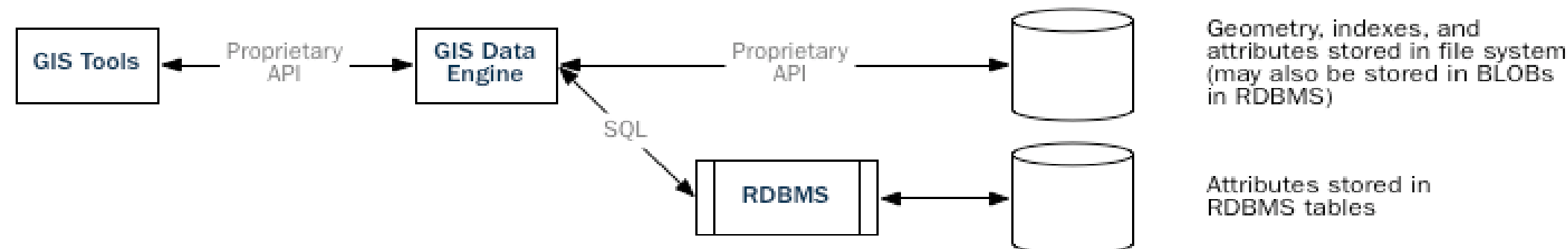
GIS & Data Modeling

Evolution of GIS Architectures

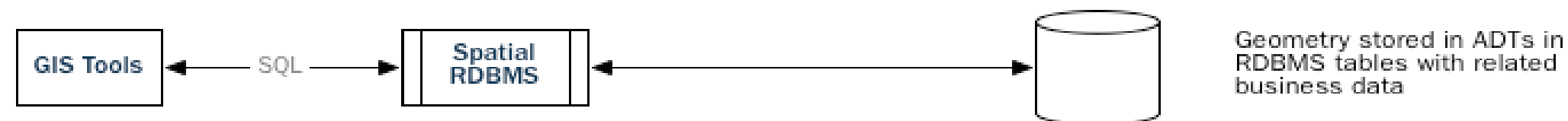
First-Generation GIS:



Second-Generation GIS:



Third-Generation GIS:



What is data modeling?

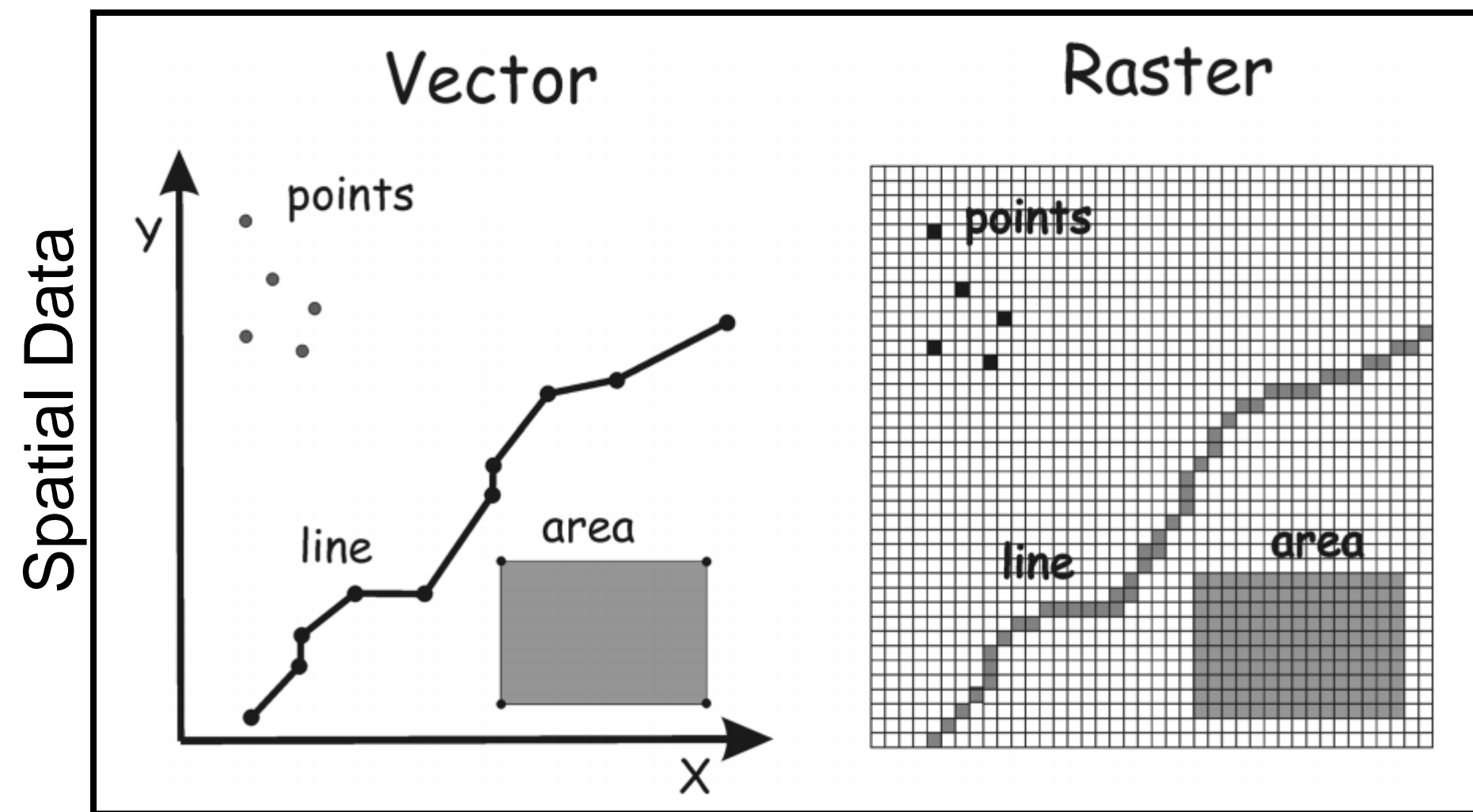
- Data model is an abstract representation that includes most important aspects of a given problem



→ Professor (EmployeeID, Name, Address, Department, Rank, Salary, ..)

→ Patient (PatientID, Name, Address, BloodType, Height, Weight, ..)

Spatial Data Models



Information

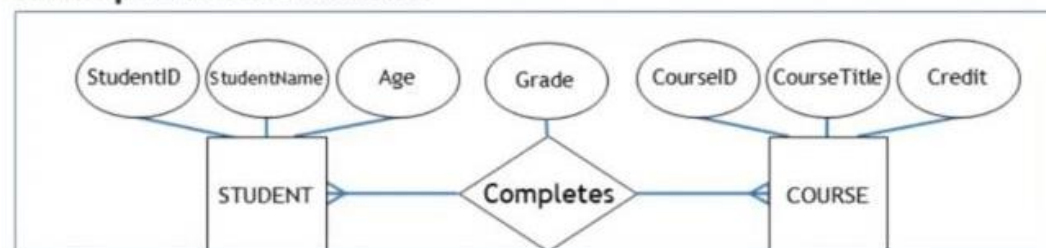
Discrete	Continuous
<ul style="list-style-type: none">• Building No• Road Name• Parcel ID	<ul style="list-style-type: none">• Temperature• Elevation

Data Modeling Steps

What is data modeling?

- Steps in data modeling for DBMS
 - **Conceptual modeling**: the highest-level relationships between the different entities
 - **Logical modeling**: more details such as keys, all the attributes, normalization etc..
 - **Physical modeling**: the actual design or the way how a database is stored to computer

Conceptual data model:



Logical data model:

Student(StudentID, StudentName, Age)
 Course (CourseID, CourseTitle, Credit)
 Completes (StudentID, CourseID, Grade)

Physical data model: indexing, column constraint, column data type..

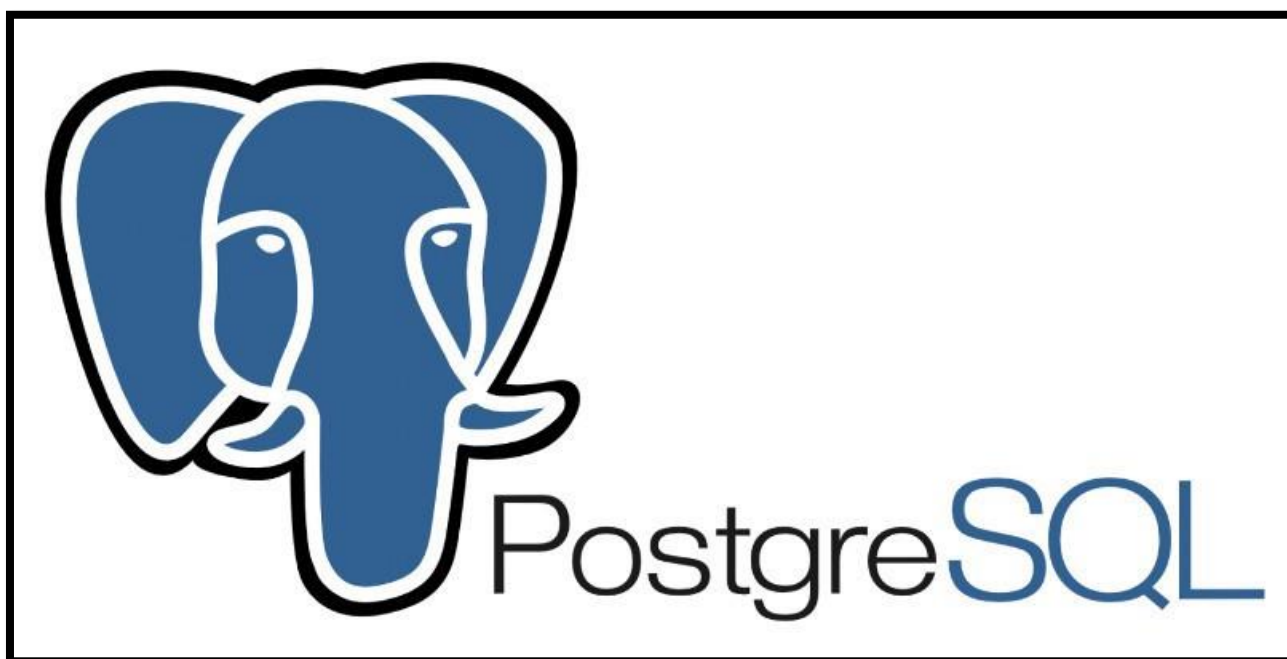
Student(StudentID Char[10], StudentName Char[30], Age INT)
 ...

- The main task for the GIS analyst is the construction of the conceptual computational model for the database, termed a conceptual data model.
- A GIS designer will then tailor the conceptual data model to the particular kind of DBMS on which the system will be implemented, called a logical data model.
- For example, if the DBMS is relational, then part of the design stage will be the creation of relation schemes.
- Third stage is the implementation of logical model being dependent of the details of physical properties of selected DBMS.

Spatial Database Management Systems & PostGIS



A system that offers spatial data types in its data model and query language, and supports spatial data types in its implementation, providing at least spatial indexing and spatial join methods.



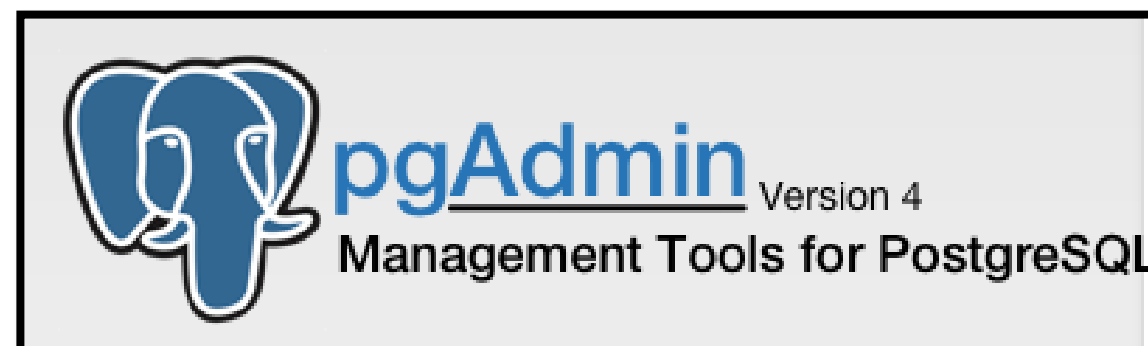
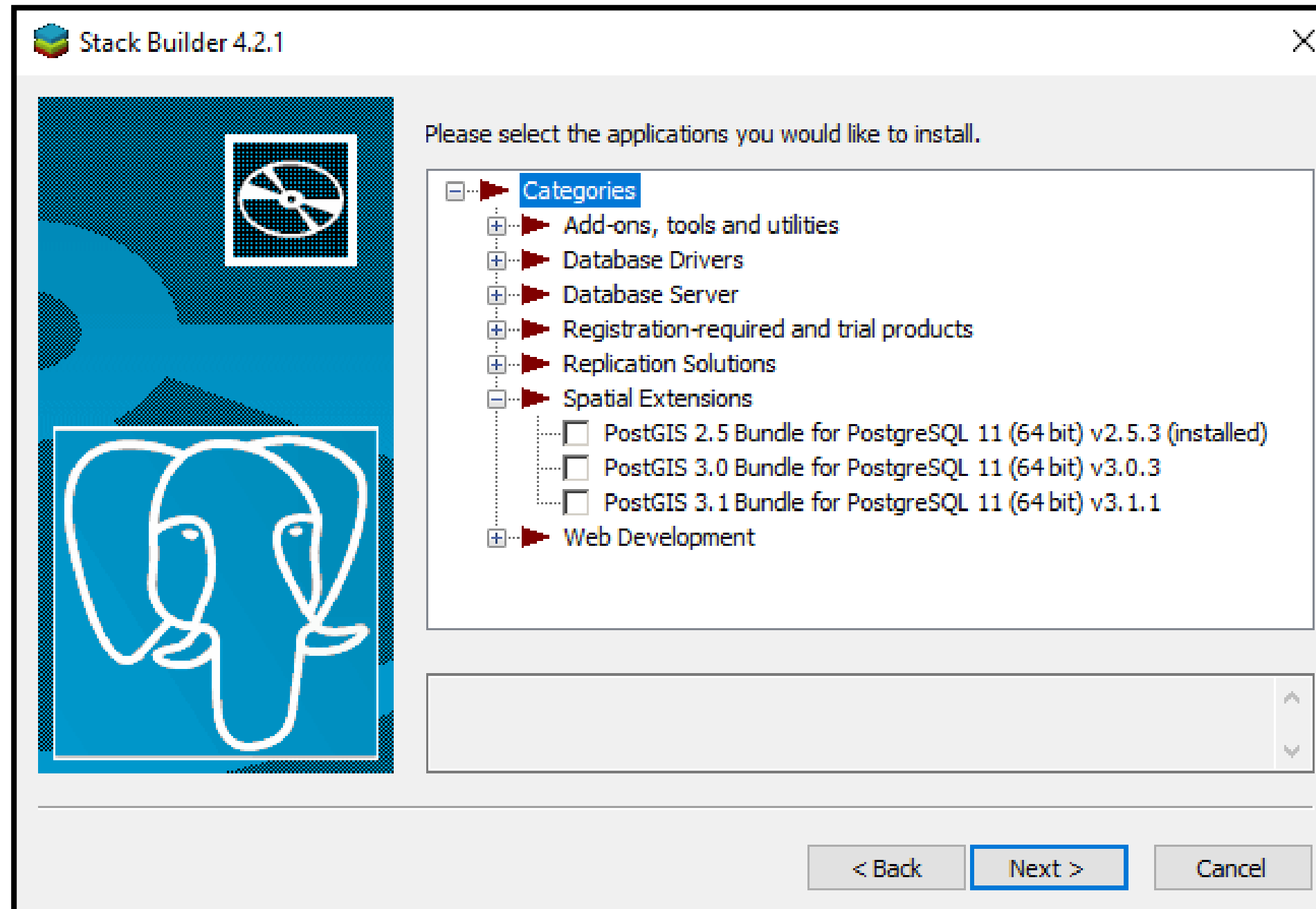
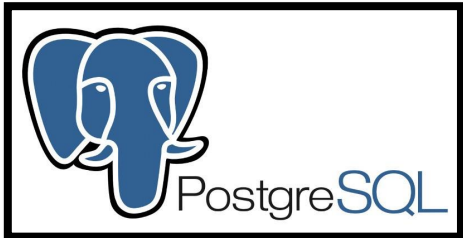
PostgreSQL is a powerful, open source object-relational database system that uses and extends the SQL language combined with many features that safely store and scale the most complicated data workloads.

PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing location queries to be run in SQL.

<https://www.postgresql.org/download/windows/>

Download the installer certified by EDB for all supported PostgreSQL versions.

PostGIS Installation



Introduction to PostgreSQL

Unlock Saved Passwords

Please enter your master password.
This is required to unlock saved passwords and reconnect to the database server(s).

Password

pgAdmin File Object Tools Help

Browser Dashboard Properties SQL Statistics Dependencies **Dependents**

Servers (1)
PostgreSQL 11
Databases (2)
personal
postgres
Login/Group Roles
Tablespaces

No dependent information is available for the selected object.

Creating a database

Servers (1)
PostgreSQL 11
Databases (2)
personal
postgres
Login/Group Roles
Tablespaces

Create Database...
Refresh...

Create - Database

General Definition Security Parameters Advanced SQL

Database gislecture

Owner postgres

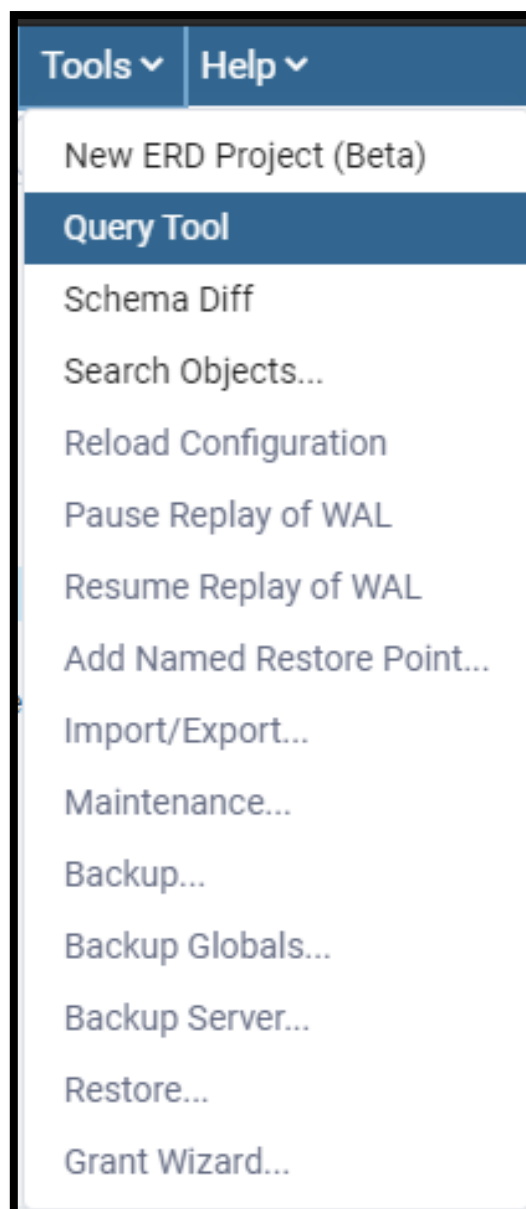
Comment

Servers (1)
PostgreSQL 11
Databases (3)
gislecture
Casts
Catalogs
Event Triggers
Extensions (1)
plpgsql
Foreign Data Wrappers
Languages
Schemas
personal
postgres
Login/Group Roles
Tablespaces

Enabling PostGIS



Copy and Paste this in the query tool*



```
CREATE EXTENSION postgis; -- Enable Topology
CREATE EXTENSION postgis_topology; -- Enable PostGIS Advanced 3D -- and
other geoprocessing algorithms
CREATE EXTENSION postgis_sfcgal; -- fuzzy matching needed for Tiger
CREATE EXTENSION fuzzystmatch; -- rule based standardizer
CREATE EXTENSION address_standardizer; -- example rule data set
CREATE EXTENSION address_standardizer_data_us; -- Enable US Tiger
Geocoder
CREATE EXTENSION postgis_tiger_geocoder; -- routing functionality
CREATE EXTENSION pgrouting; -- spatial foreign data wrappers
CREATE EXTENSION ogr_fdw; -- LIDAR support
CREATE EXTENSION pointcloud; -- LIDAR Point cloud patches to geometry
type cases
CREATE EXTENSION pointcloud_postgis;
```

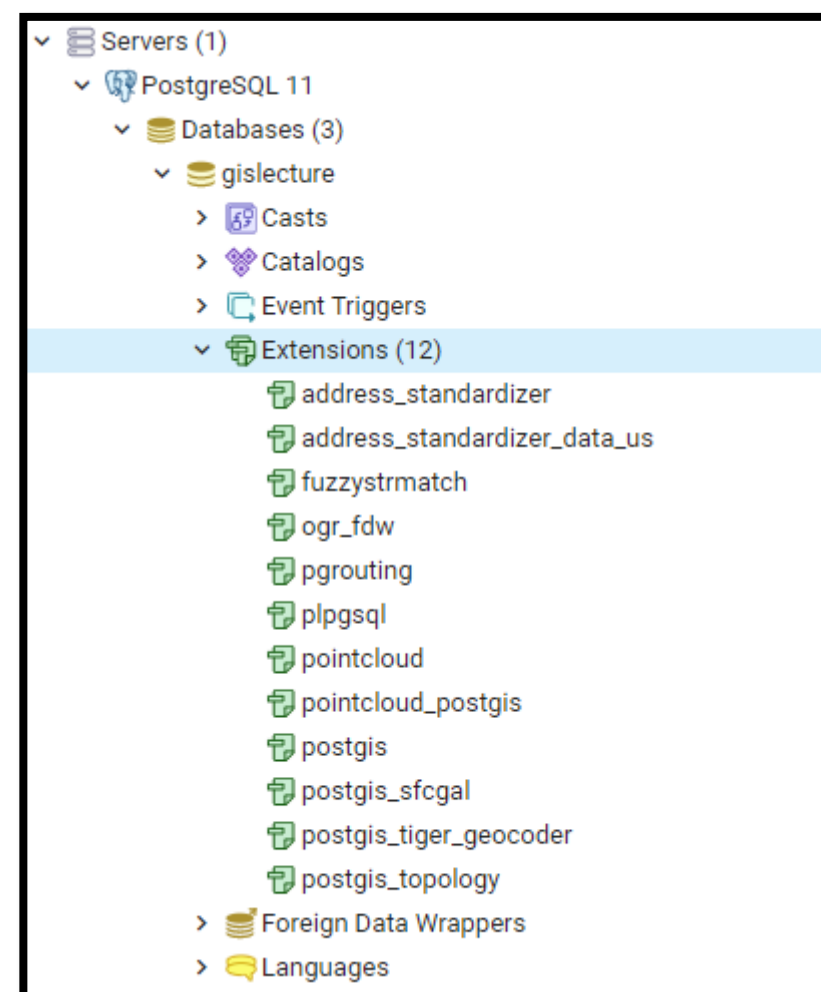
* The query is prepared to enable all spatial extensions included in PostGIS 2.5 version. “CREATE EXTENSION postgis” query is sufficient to enable PostGIS in case the query does not run on other versions

Enabling PostGIS

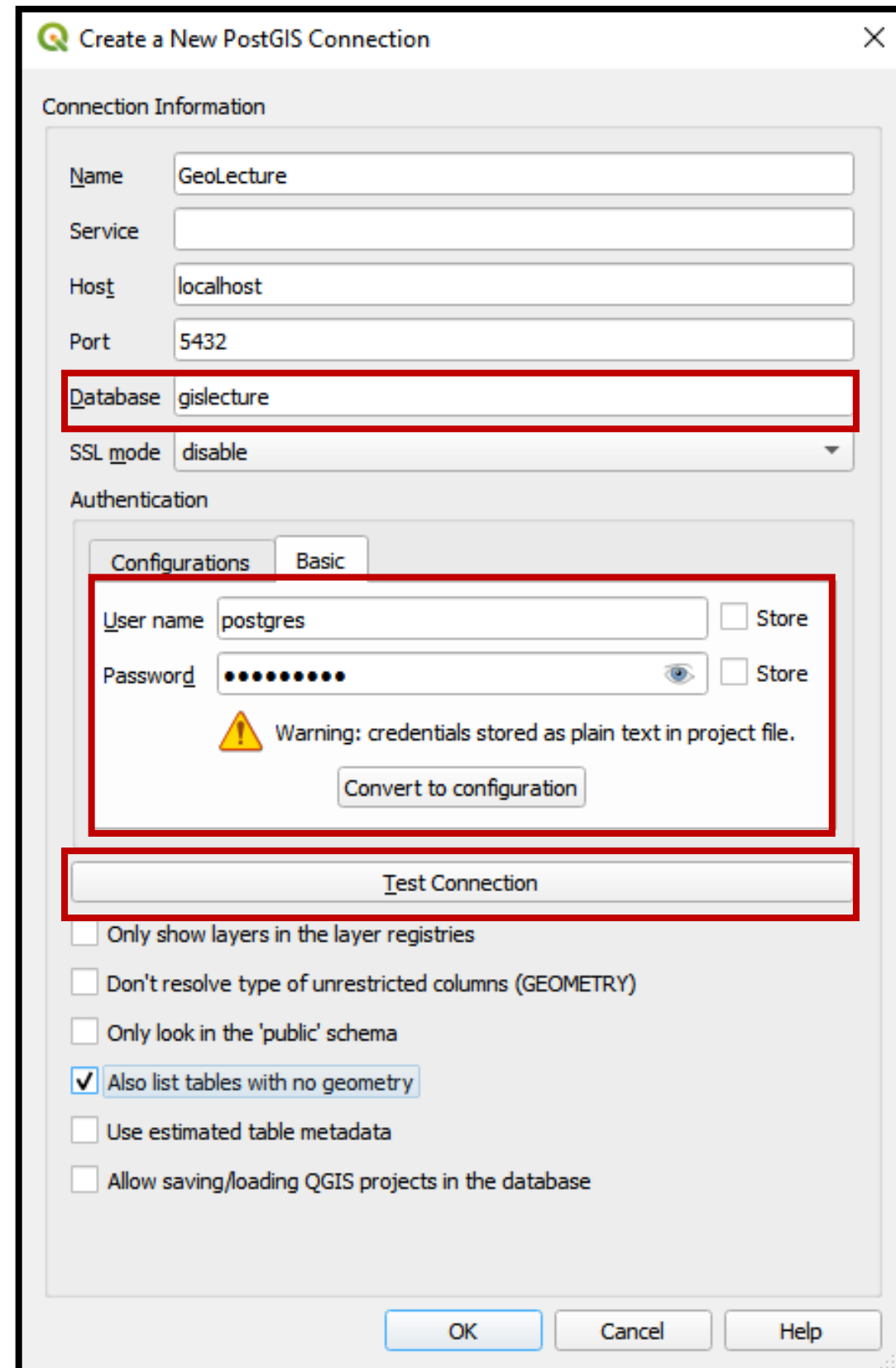
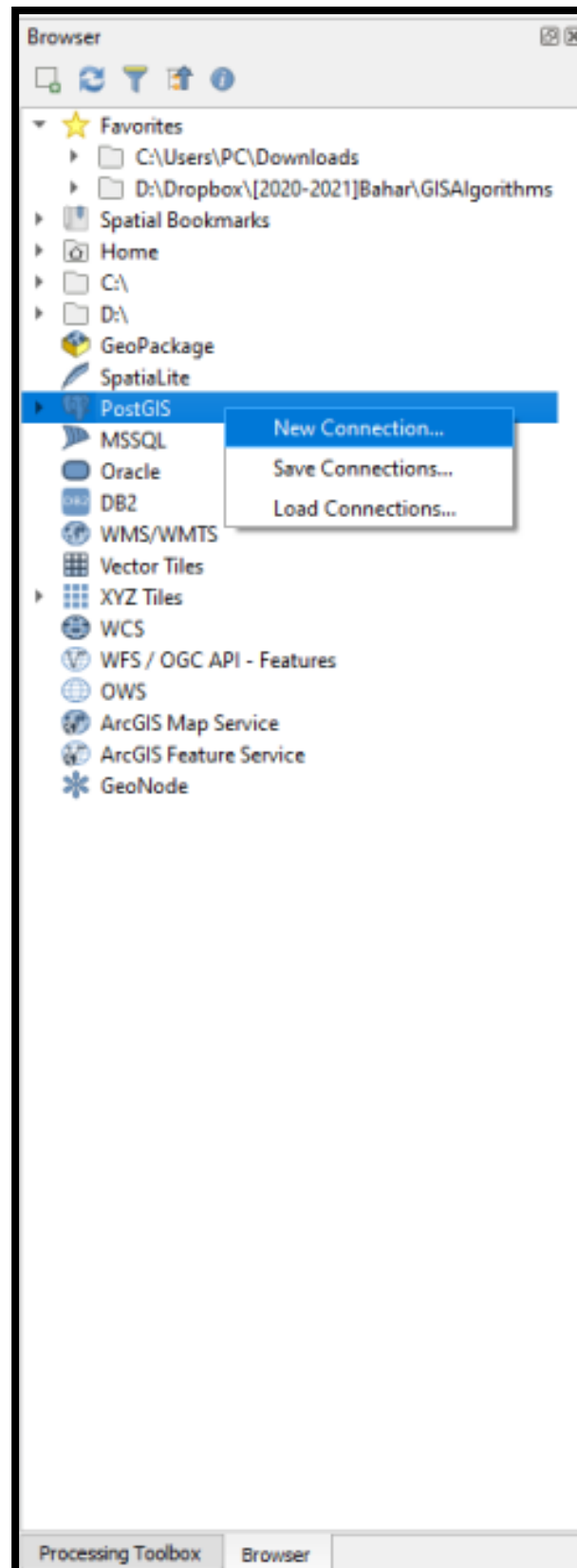


```
gislecture/postgres@PostgreSQL 11
Query Editor  Query History  Scratch Pad
1 CREATE EXTENSION postgis; -- Enable Topology
2 CREATE EXTENSION postgis_topology; -- Enable PostGIS Advanced 3D -- and other geoprocessing algorithms
3 CREATE EXTENSION postgis_sfcgal; -- fuzzy matching needed for Tiger
4 CREATE EXTENSION fuzzystmatch; -- rule based standardizer
5 CREATE EXTENSION address_standardizer; -- example rule data set
6 CREATE EXTENSION address_standardizer_data_us; -- Enable US Tiger Geocoder
7 CREATE EXTENSION postgis_tiger_geocoder; -- routing functionality
8 CREATE EXTENSION pgrouting; -- spatial foreign data wrappers
9 CREATE EXTENSION ogr_fdw; -- LIDAR support
10 CREATE EXTENSION pointcloud; -- LIDAR Point cloud patches to geometry type cases
11 CREATE EXTENSION pointcloud_postgis;
```

**Run the Query by
Pressing F5**



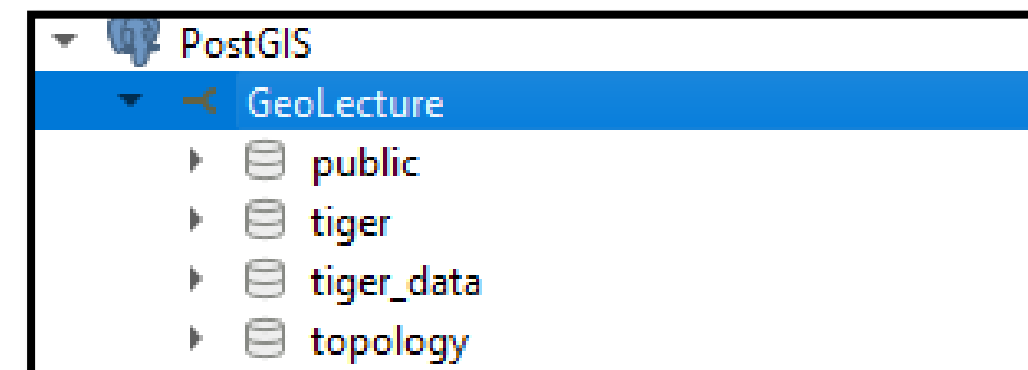
QGIS & PostGIS Connection



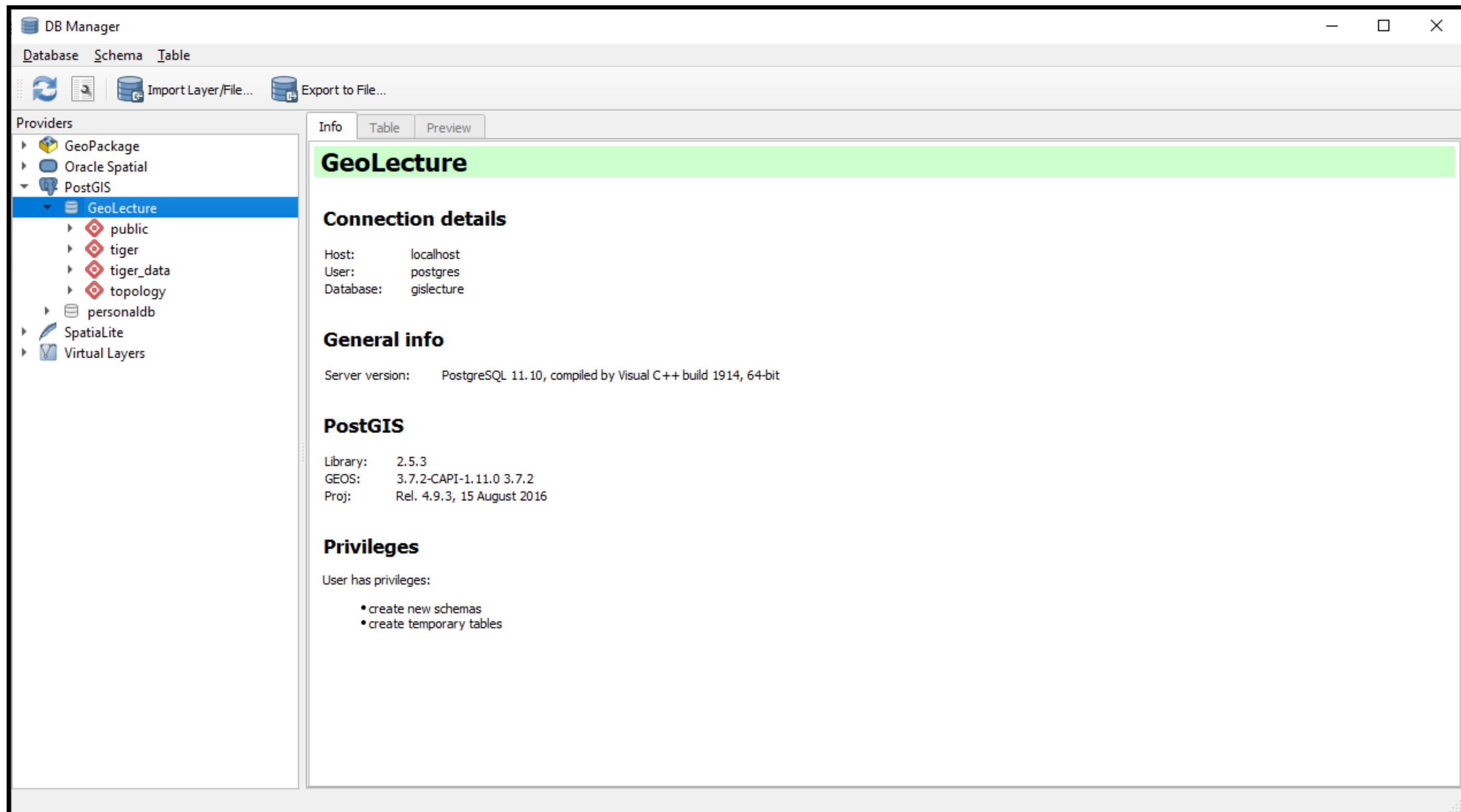
Database name in PostgreSQL

You can select Store if you are working on a local computer

Test Connection first



Database Manager in QGIS



Aim of the Study



Aim of the Study:

- *Implement the following spatial database development stages*
 - *Conceptual Model*
 - *Logical Model*
 - *Physical Model*
- about the effects on a possible flood event in different scopes for the Association of Local Administrations*

Questions:

- *Which schools will be affected in the districts of European side of Istanbul?*
- *Which residential areas will be affected?*
- *How long primary road will be affected in each district?*
- *How much cost will the affected buildings cause?*

Input Data:

- *What kind of spatial & non-spatial data are needed for this application?*

Data & Requirements

Questions:

- *Which schools will be affected in the districts of European side of Istanbul?*
- *Which residential areas will be affected?*
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- *How much cost will the affected buildings cause?*

Input Data:

- *What kind of spatial & non-spatial data are needed for this application?*

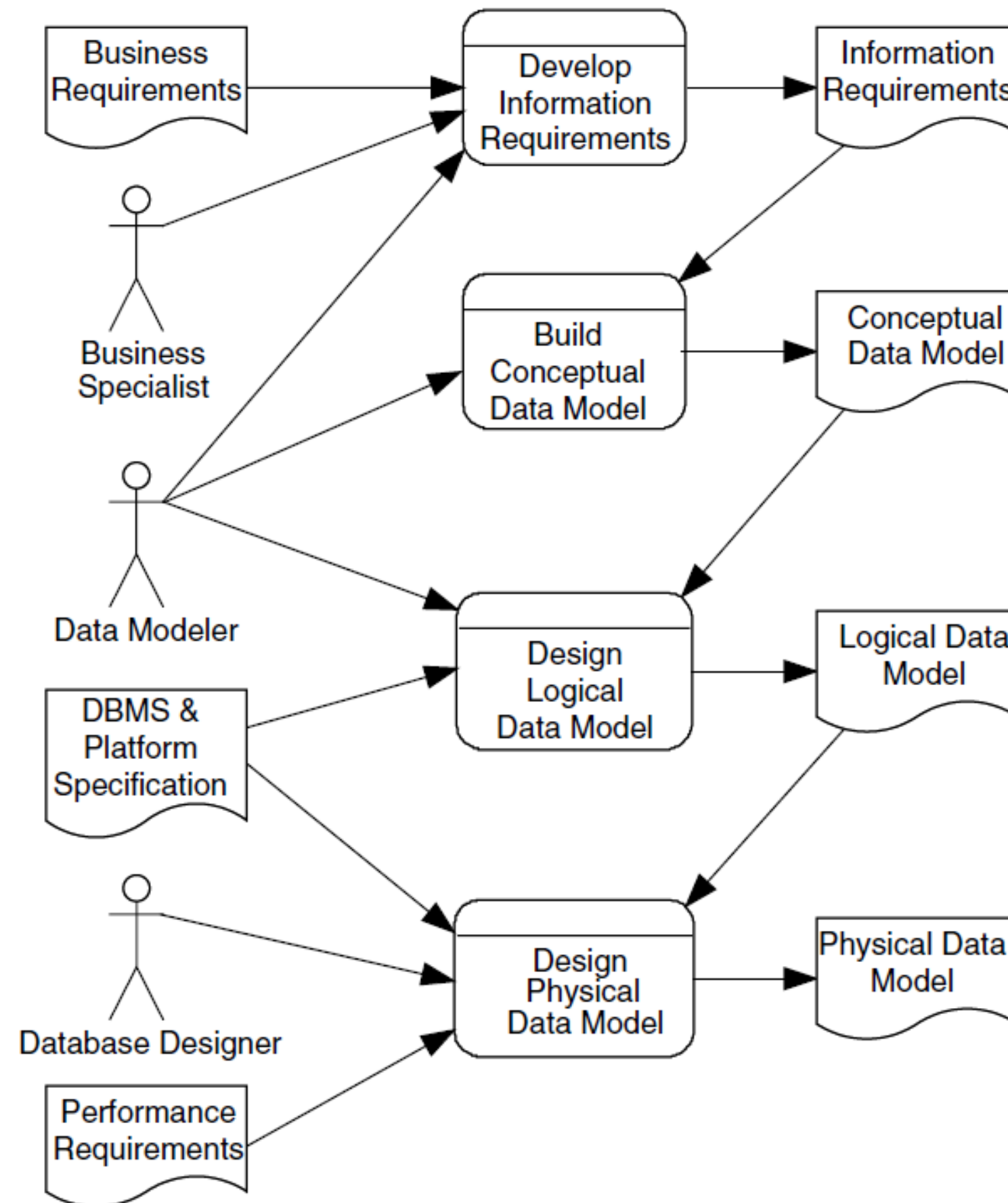
To answer the questions of Association of Local Administrations we need:

- *Province boundaries to get European Side of Istanbul*
- *Districts of Istanbul*
- *Roads with their hierarchy*
- *Point of Interests contains school locations*
- *Buildings with some economic inputs*
- *Residential areas*

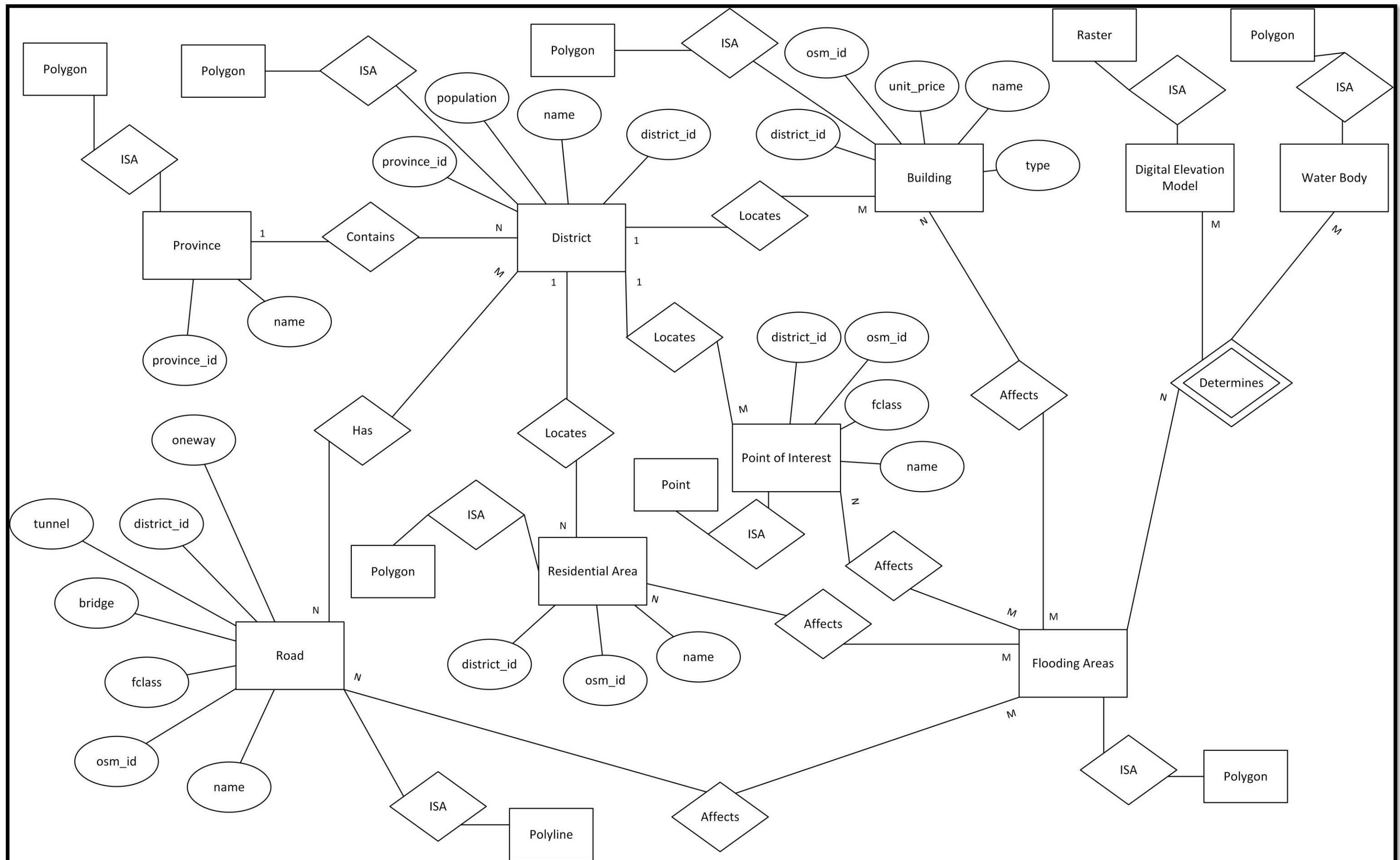
To make spatial flood analysis we need:

- *Digital Elevation Model*
- *Water Areas*

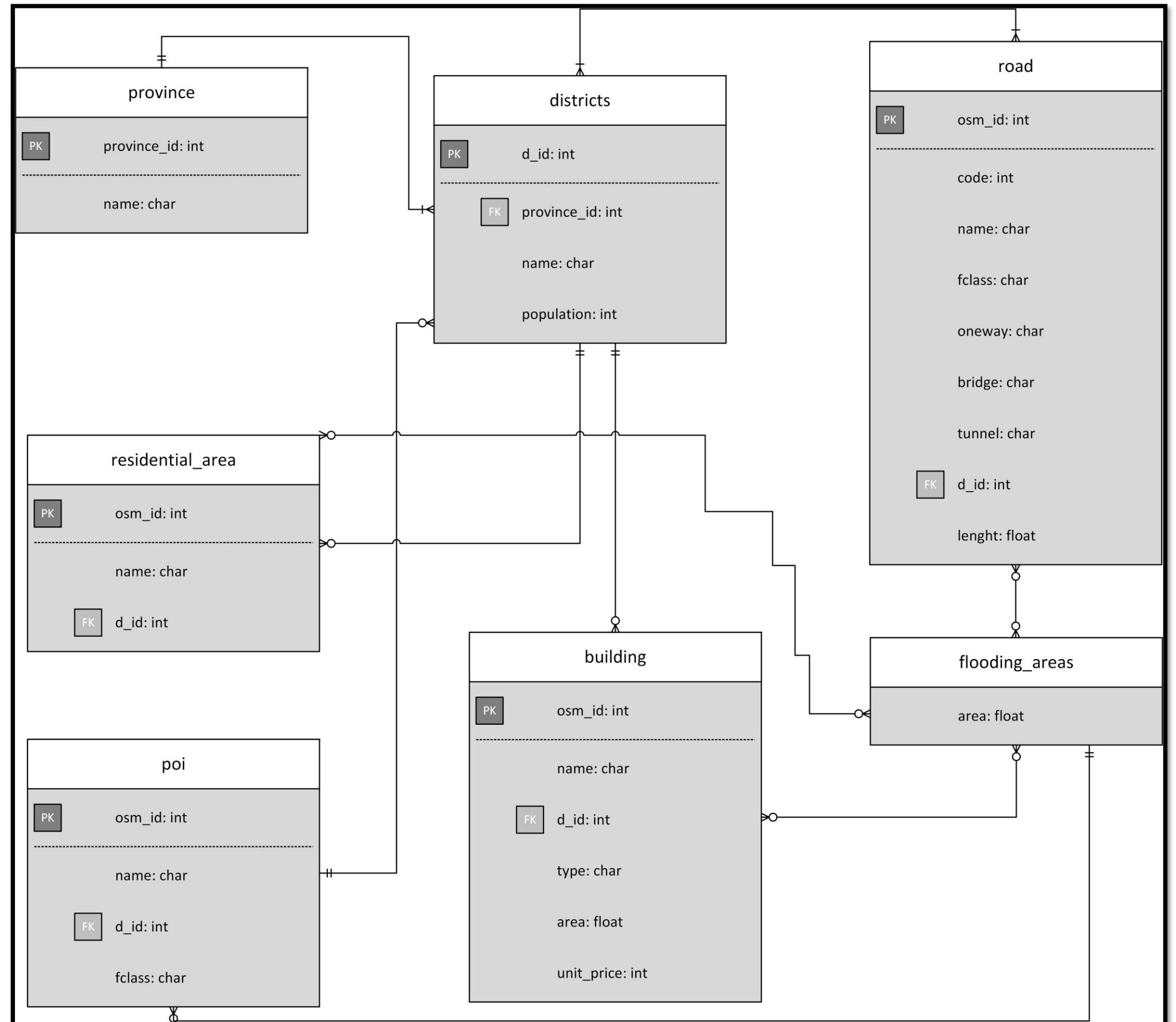
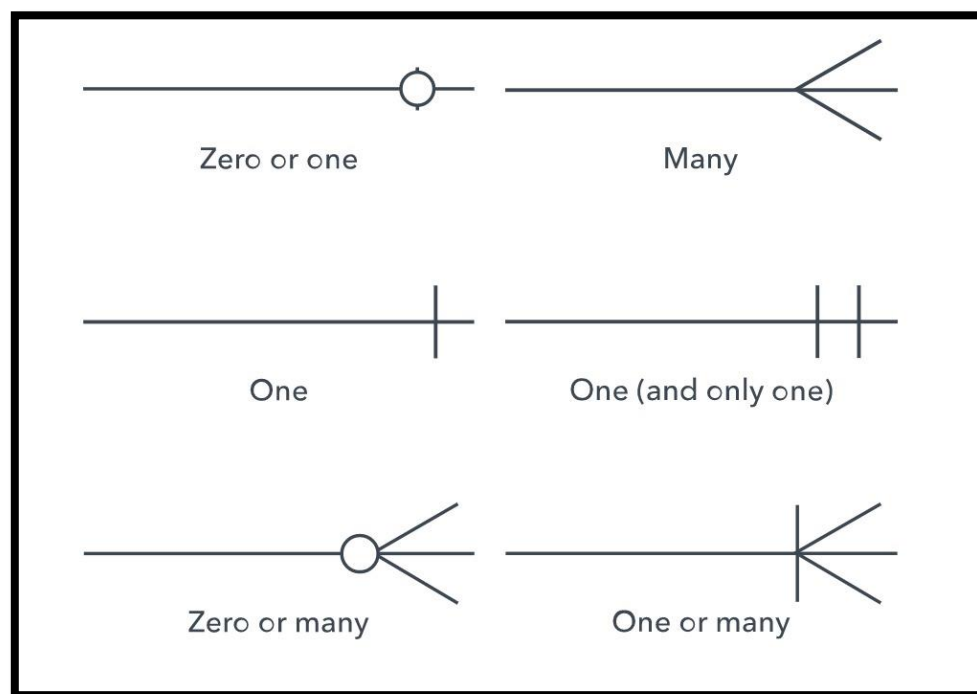
Database Design Tasks and Deliverables



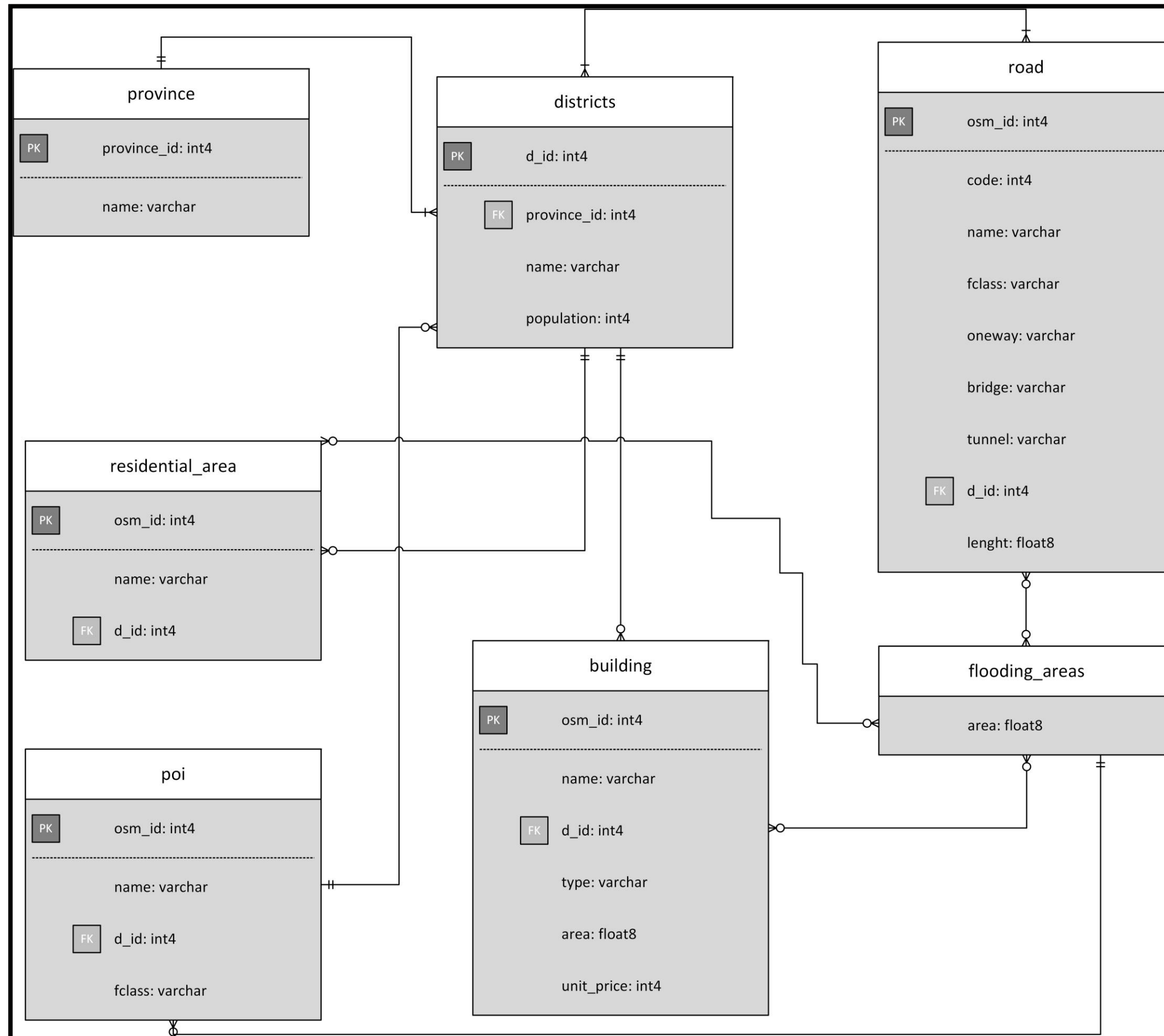
Designing a Conceptual Model Chen's Notation



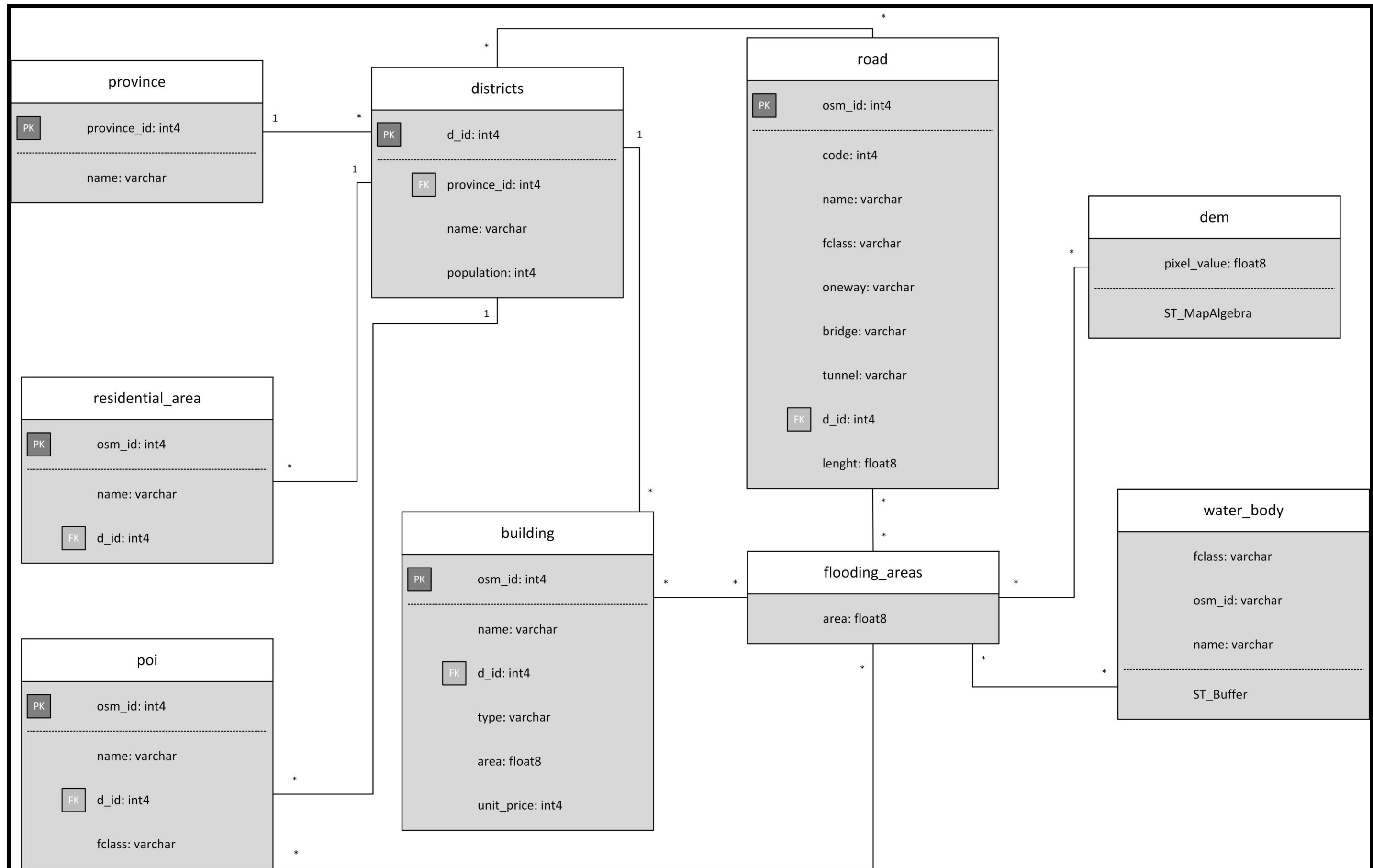
Designing a Logical Model Crow's Foot Notation



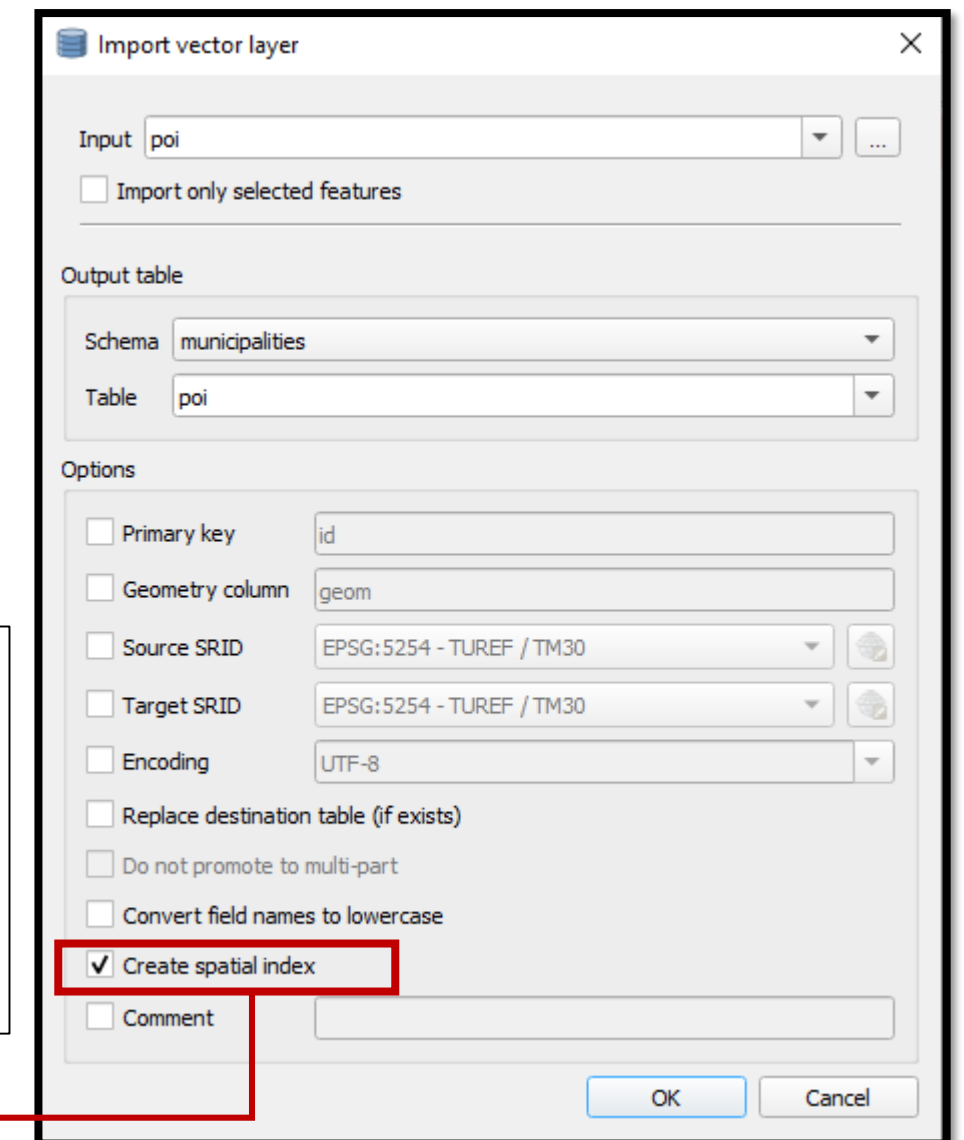
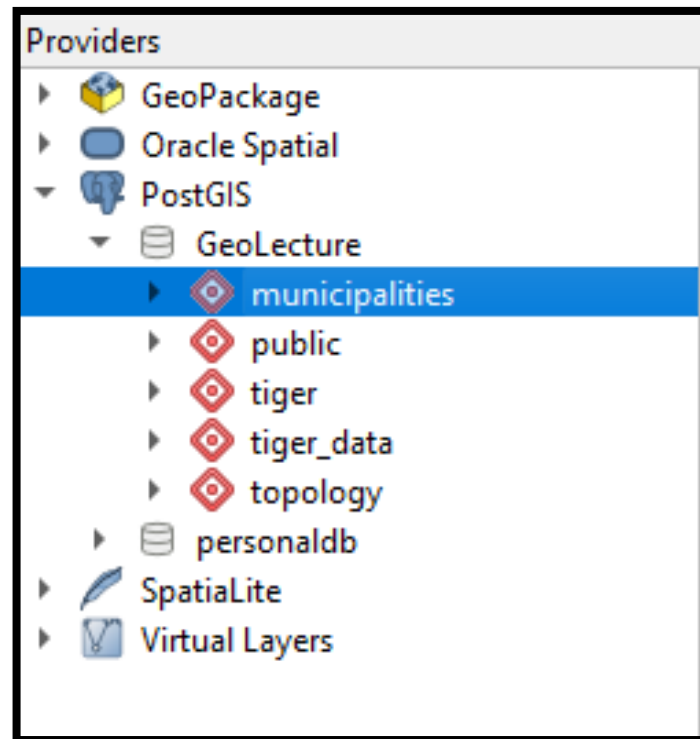
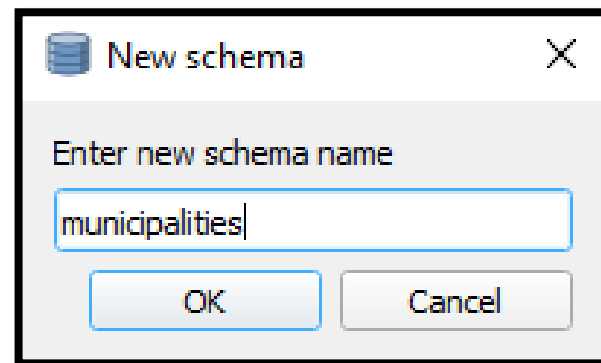
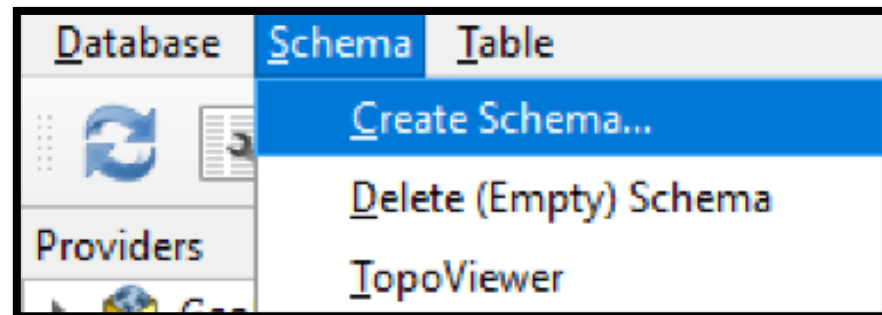
Constructing Physical Model



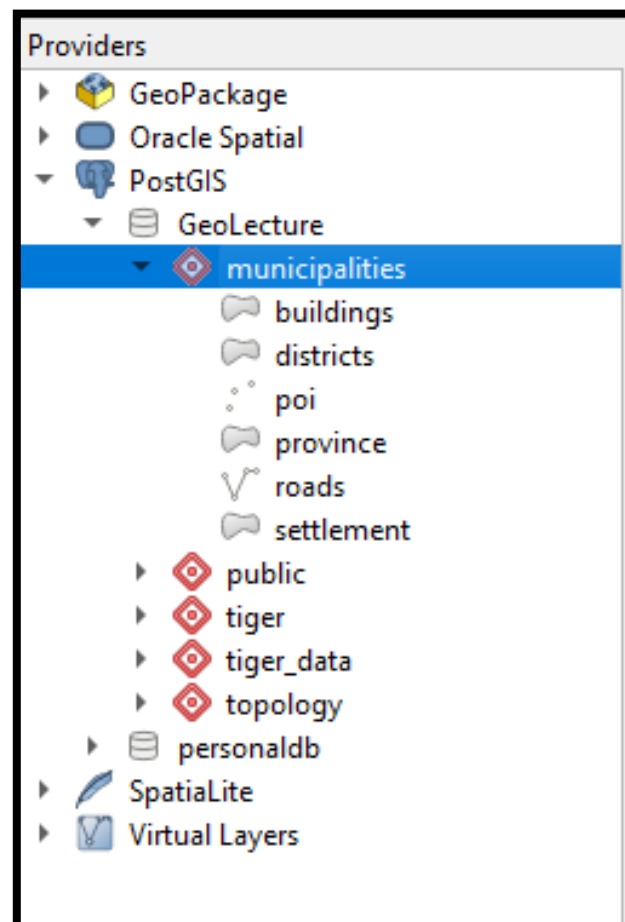
UML Notation



Importing Data to PostgreSQL



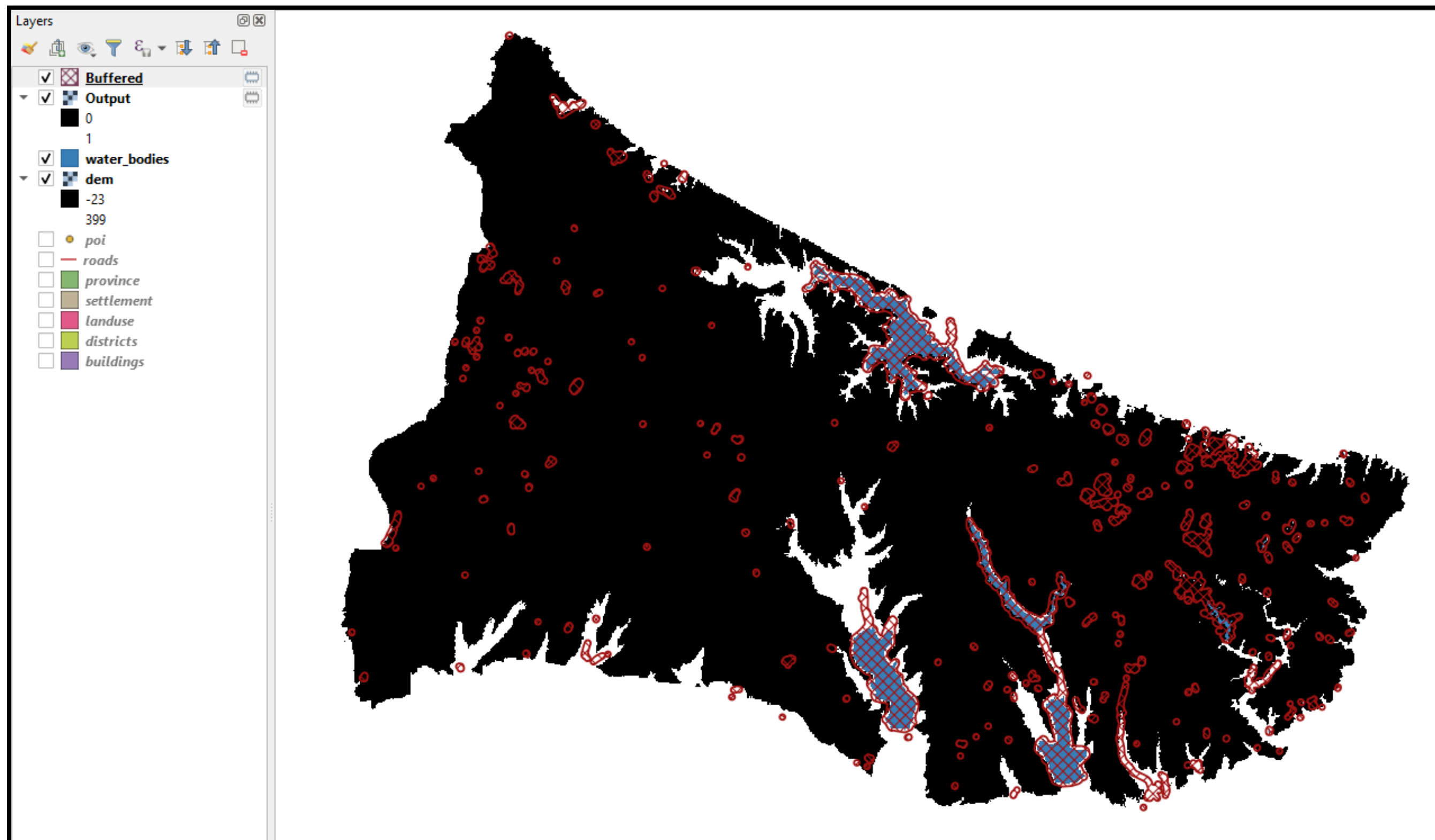
Drag **province, district, roads, poi, settlement** and **buildings** to the QGIS Layers window. And Import them one by one into PostgreSQL



Spatial Indexing is one of the key features in Spatial DBMS

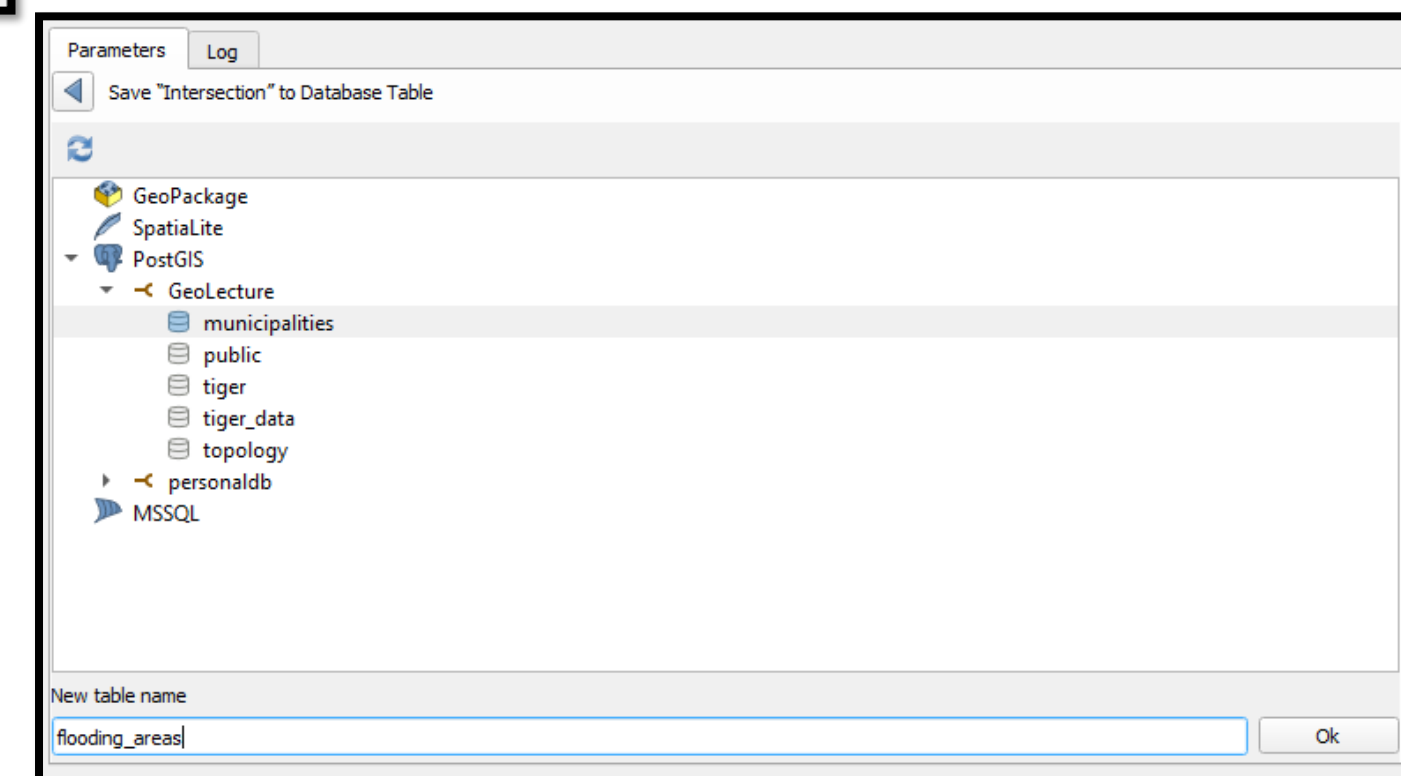
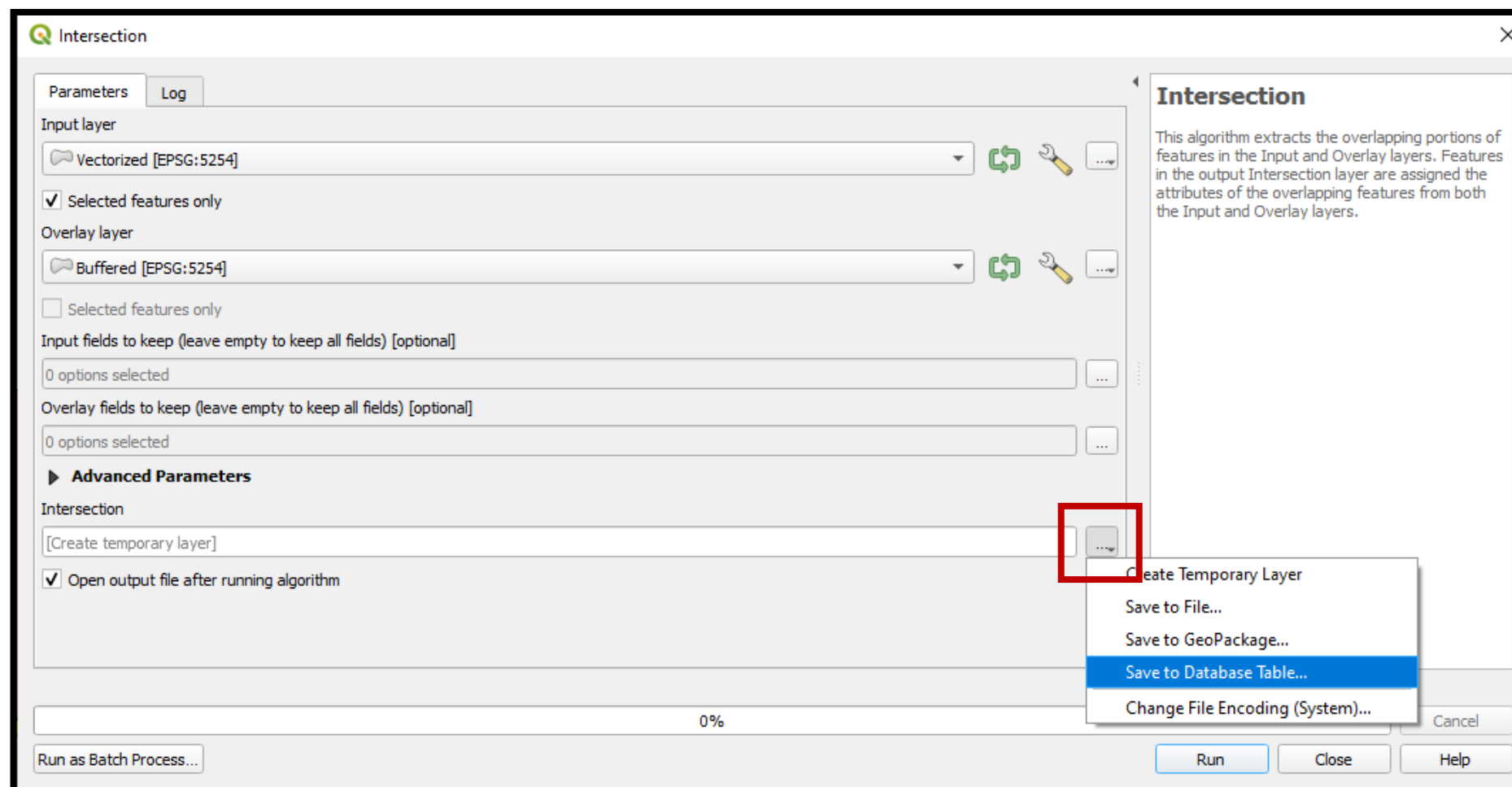
Perform a Simple Flood Analysis

- Apply a 250 m buffer distance to water_bodies
- Use Raster Calculator to find places have elevation below 25 m

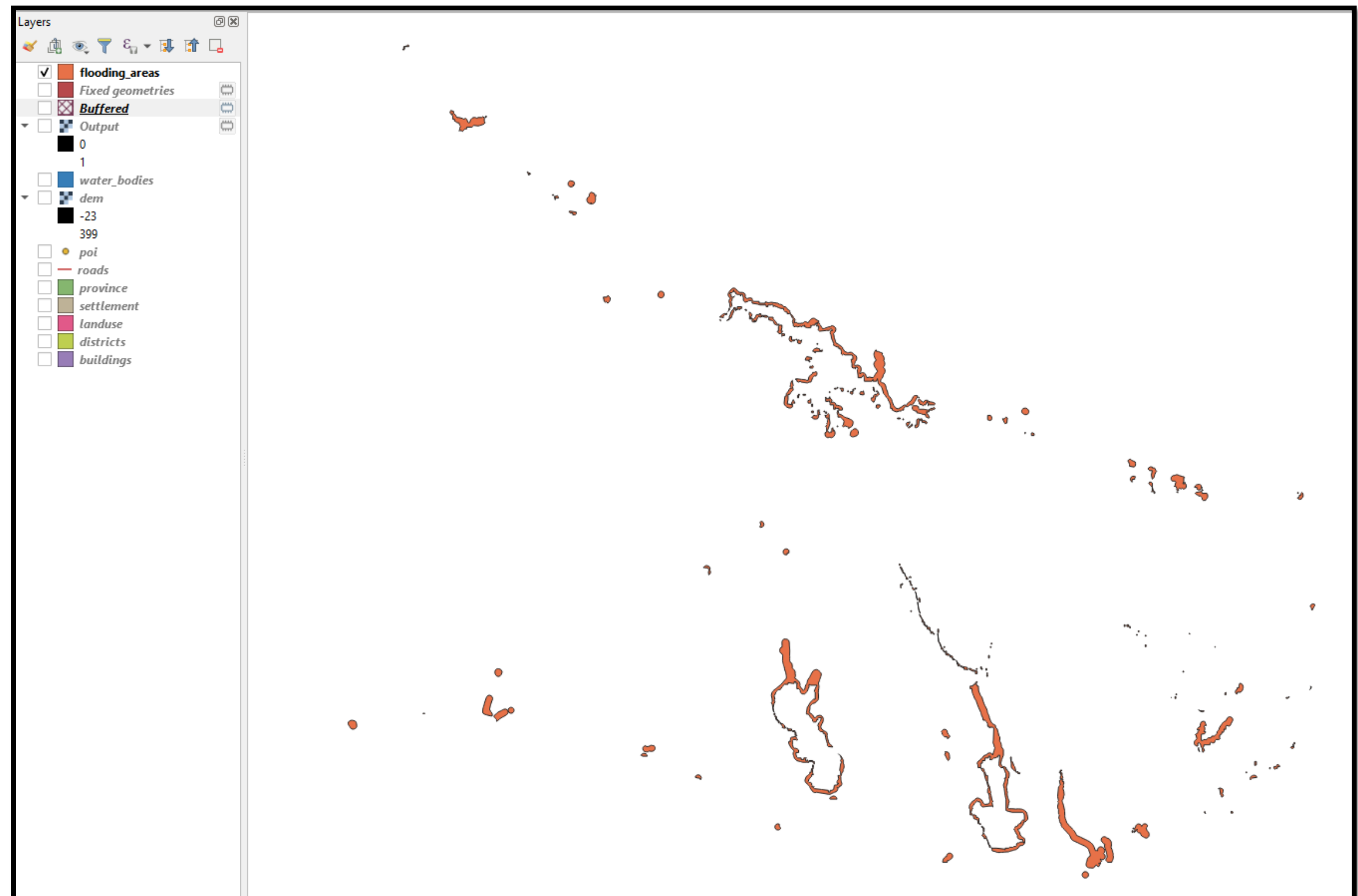
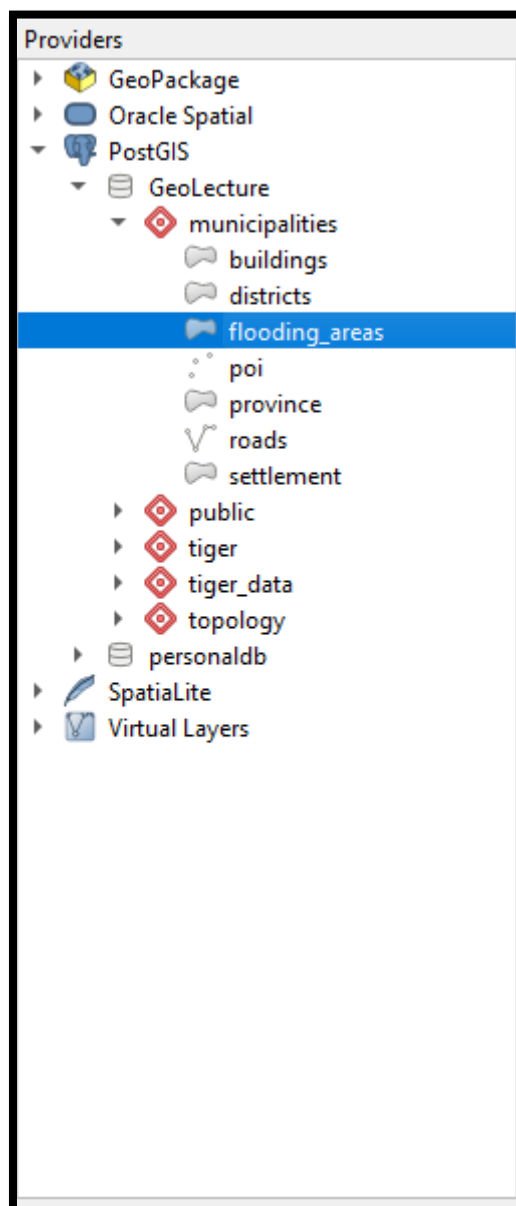


Perform a Simple Flood Analysis

- Use Raster Vector conversion and intersect two conditions to find flooding_areas



Flood Analysis Results



Question 1



- Which schools will be affected in the districts of European side of Istanbul?

DB Manager

Database Schema Table

Import Layer/File... Export to File...

Providers

- GeoPackage
- Oracle Spatial
- PostGIS
 - GisLecture
 - municipalities
 - buildings
 - districts
 - flooding_areas
 - poi
 - province
 - roads
 - settlement
 - public
 - tiger
 - tiger_data
 - topology
 - personaldb
 - Spatialite
 - Virtual Layers

Info Table Preview Query (GisLecture) X

Saved query [Name] [Save] [Delete] [Load File] [Save As File]

```
1 SELECT p.*, m.ilce_adi FROM municipalities.poi AS p, municipalities.districts AS m, municipalities.flooding_areas AS f
2 WHERE p.d_id = m.d_id AND st_intersects(p.geom, f.geom) AND p.fclass = 'school' ORDER BY ilce_adi
```

Execute 4 rows, 0.137 seconds Create a view Clear Query History

	id	geom	fid	osm_id	code	fclass	name	d_id	ilce_adi
1	6192	0104000020861...	6192	5053706856	2082	school	Pertevniyal Lisesi	29	Fatih
2	6469	0104000020861...	6469	5081274337	2082	school	Oruçgazi Ortao...	29	Fatih
3	17060	0104000020861...	17060	4511934494	2082	school	Nurullah Baldö...	13	Silivri
4	17127	0104000020861...	17127	5094968923	2082	school	Hasan Özvarnal...	13	Silivri

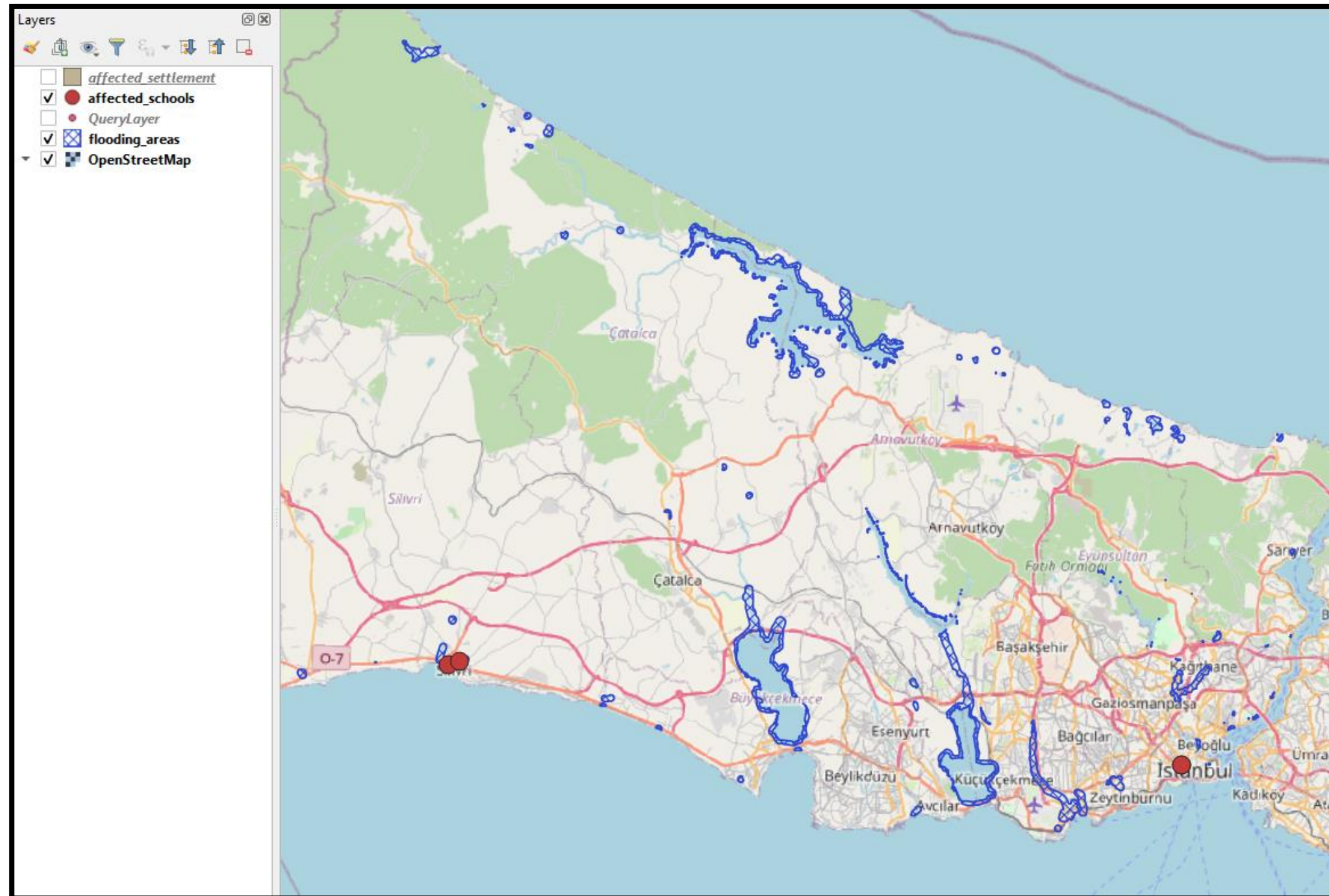
☒ Load as new layer

☒ Column(s) with unique values id ☒ Geometry column geom Retrieve columns

Layer name (prefix) affected_schools Set filter

☐ Avoid selecting by feature id Load Cancel

Result of Question 1



Save the output as affected_schools.geojson and sql query as query1.sql

affected_schools — Features Total: 4, Filtered: 4, Selected: 0

	id	osm_id	code	fclass	name	d_id	ilce_adi
1	17060	875901233	2082	school	Nurullah Baldö...	13	Silivri
2	6192	892351795	2082	school	Pertevniyal Lisesi	29	Fatih
3	6469	892352561	2082	school	Oruçgazi Ortao...	29	Fatih
4	17127	892352820	2082	school	Hasan Özvarnal...	13	Silivri

Question 2



- Which residential areas will be affected?

The screenshot shows the QGIS DB Manager interface. On the left, the 'Providers' list includes GeoPackage, Oracle Spatial, and PostGIS. Under PostGIS, the 'GisLecture' database is expanded, showing tables like 'municipalities', 'buildings', 'districts', 'flooding_areas', 'poi', 'province', 'roads', and 'settlement'. The 'Query (GisLecture)' tab is active, displaying a SQL query:

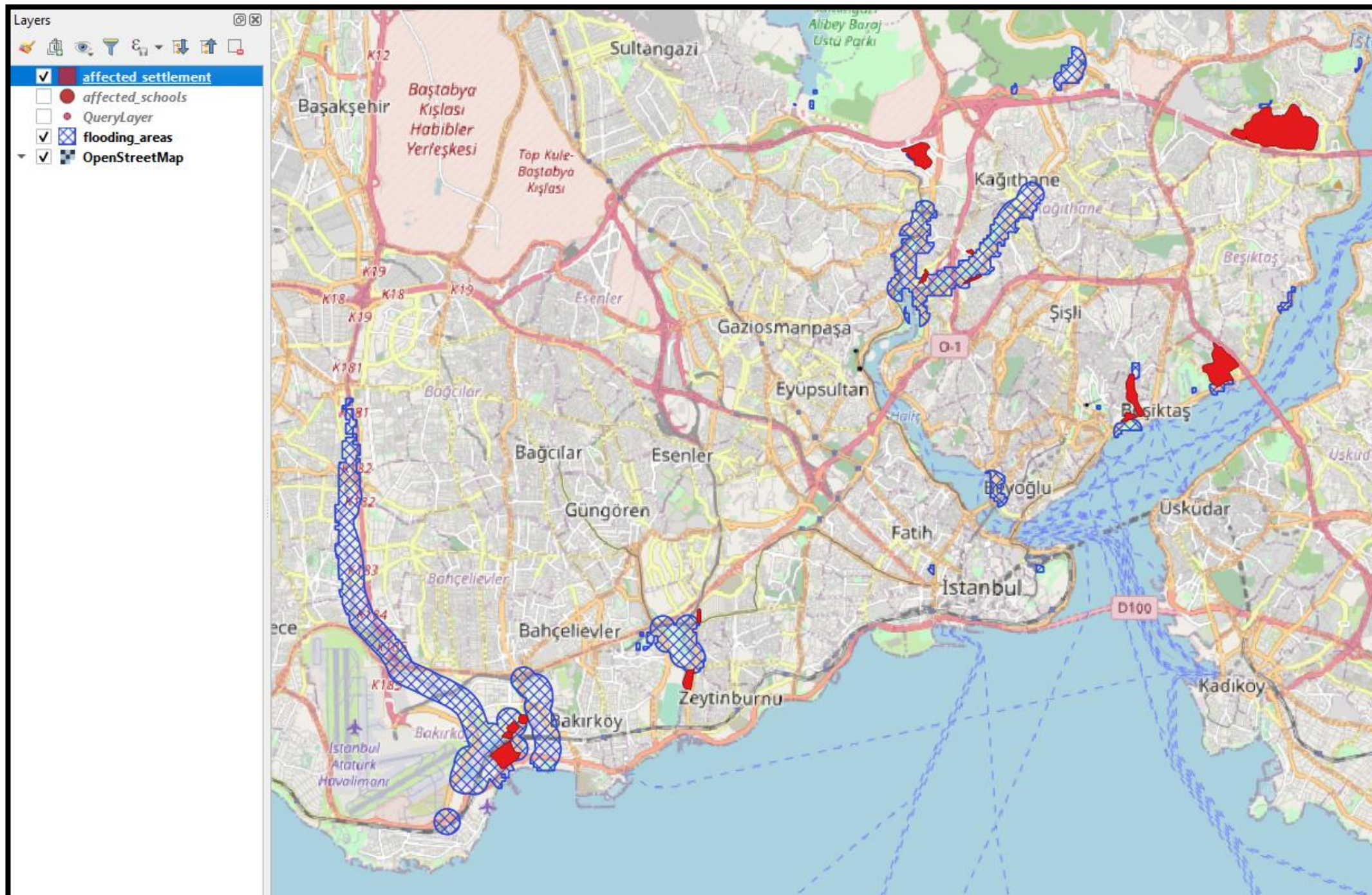
```
1 SELECT s.*, m.ilce_adi FROM municipalities.settlement AS s, municipalities.districts AS m, municipalities.flooding_areas AS f
2 WHERE s.d_id = m.d_id AND st_intersects(s.geom, f.geom) ORDER BY ilce_adi
```

Below the query, the results are shown in a table with 8 columns: id, geom, fid, osm_id, name, d_id, and ilce_adi. The table contains 6 rows of data. At the bottom, the 'Load as new layer' section is visible, with options to load the query as a new layer, including a checkbox for 'Column(s) with unique values' (set to 'id') and a checkbox for 'Geometry column' (set to 'geom'). The 'Layer name (prefix)' is set to 'affected_settlement'.

	id	geom	fid	osm_id	name	d_id	ilce_adi
1	163	0106000020861...	163	386491559	NULL	5	Arnavutköy
2	423	0106000020861...	423	389520095	TOKİ Ataköy Ko...	30	Bakırköy
3	428	0106000020861...	428	455579496	Martı Sitesi	30	Bakırköy
4	426	0106000020861...	426	405820312	Bahar Sitesi	30	Bakırköy
5	425	0106000020861...	425	405820106	Işık Sitesi	30	Bakırköy
6	683	0106000020861...	683	764388597	Berit 08	20	Başakşehir

You can save & load SQL query in .sql format to later use in another environment

Result of Question 2



Save the output as affected_settlement.geojson and sql query as query2.sql

affected_settlement — Features Total: 40, Filtered: 25, Selected: 0

	id	osm_id	name	d_id	ilce_adi
1	866	909521458	NULL	37	Büyüçekmece
2	890	3762818173136...	NULL	14	Sarıyer
3	72	909587763	Erdemkent Sitesi	13	Silivri
4	753	892940850	Ahikent Villaları	34	Eyüp
5	163	859321908	NULL	5	Arnavutköy
6	847	926234418	NULL	34	Eyüp
7	334	875968305	NULL	8	Zeytinburnu
8	428	875902261	Martı Sitesi	30	Bakırköy
9	423	859322677	TOKİ Ataköy Ko...	30	Bakırköy
10	850	942748216	Arya Konutları	17	Kağıthane
11	371	858863158	Istanbul Loung...	27	Küçükçekmece
12	380	859387445	Dumankaya Ko...	27	Küçükçekmece
13	701	926299441	Doğa Parkı Evleri	20	Başakşehir
14	375	859387191	NULL	27	Küçükçekmece
15	426	875574584	Bahar Sitesi	30	Bakırköy
16	743	892351537	5. Levent	34	Eyüp

Show All Features

Results & Take Home

Our questions were

- *Which schools will be affected in the districts of European side of Istanbul?*
- *Which residential areas will be affected?*
- *How long primary road will be affected in each district?*
- *How much cost will the affected buildings cause?*

Output Data:

- *Flooding Areas (Vector-Geojson/Polygon)*
- *Affected Schools (Vector-Geojson/Point)*
- *Affected Settlements (Vector-Geojson/Polygon)*

Take Home Part

- *Try to build conceptual/logical and physical model to determine the types of affected railways (train, metro etc.) and protected areas (forest, archeological etc.)*
- *Try to install PostgreSQL & PostGIS properly, apply the workflow we have done on your own computer and check that you get the same results.*
- *Try to find the answers of last two questions using PostGIS*

References



- Calkins, H. W. (1996). Entity relationship modeling of spatial data for geographic information systems. *International Journal of Geographical Information Systems*, 10(1).
- Güting, R. H. (1994). An introduction to spatial database systems. *the VLDB Journal*, 3(4), 357-399.
- Introduction to PostGIS. (2012). Available at: <https://postgis.net/workshops/postgis-intro/index.html>
- Joon Heo. (2021). Spatial Data Science and Applications. Coursera. Available at: <https://www.coursera.org/learn/spatial-data-science>
- Obe, R., & Hsu, L. (2015). *PostGIS in action*, Second Edition.
- Simsion, G., & Witt, G. (2004). *Data modeling essentials*. Elsevier.



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