REMOTE SENSING & GIS IN WATER RESOURCES

Paper code: 08MTRS32

Units–6, 7&8 : Geomorphic Aquifer system, Natural & Aritifical Recharge, Groundwater Modelling

Dr. K. Palanivel
Assistant Professor
Centre for Remote Sensing, Bharathidasan University

Tiruchirappalli

08MTRS-32: REMOTE SENSING & GIS IN WATER RESOURCES

1. **Surface Water Resources:** Hydrological Cycle: (Rainfall, Infiltration, Runoff, Evapotranspiration) – Global distribution of Surface Water bodies – Surface Water Budgeting/Quantification using Satellite Infrared data – Spectral Response Pattern of Water.
2. **Drainage morphometric analysis:** Drainage mapping and analysis (from Satellite data, Automated Drainage Mapping using DEM, Drainage Morphometric Analysis) Water Quality Mapping and Monitoring using Remote Sensing.
3. **Groundwater :** Basic Principles of Groundwater Hydrology
4. **Crystalline Aquifer Systems:** Characteristics, Mapping of Crystalline Aquifer Systems, Lithological, Regolith and Fracture Pattern Mapping and Modelling, Geophysical Surveys and GIS based Geospatial modelling of Crystalline Aquifer System
5. **Sedimentary Aquifer Systems:** Characteristics, Artesian and subarteisian conditions, Mapping Techniques using Geoinformatics.
6. **Geomorphic Aquifer System:** Hydro geomorphic mapping through Satellite Raw and Digitally processed data – Ground water quality (Rock – water interaction, pollution, etc).
7. **Natural and Artificial Recharge:** Site Selection for Natural and Artificial Recharge on Geological criteria, Detection of Site Specific Mechanism for recharge through GIS Applications)
8. **Groundwater Modelling:** Geospatial Modelling of Groundwater Systems – Stochastic – Flow – Linear – Finite - element Modelling.
9. **Integrated Watershed Development and Management:** Conjunctive analysis of Surface and Groundwater – GIS based Watershed wise Water budgeting – Integrated Watershed Planning – Water Resources Information System.
10. **Case studies:** Remote sensing and GIS in water resources – Case studies.

GEOMORPHIC AQUIFER SYSTEMS

1. CLASSIFICATION OF GENERAL HYDRO-GEOMORPHIC LANDFORMS
2. MAPPING OF HYDROGEOMORPHIC LANDFORMS USING REMOTE SENSING & GIS
3. EVALUATION OF AQUIFER CHARACTERISTICS OF HYDROGEOMORPHIC LANDFORMS

CLASSIFICATION OF GENERAL HYDROGEOMORPHIC LANDFORMS

TECTONIC
STRUCTURAL
DENUDATIONAL
FLUVIAL
COASTAL
MARINE
DESERTIC
GLACIAL,
Their Interface dynamic Geomorphic landforms like
Denudo-structural,
Glacio-fluvial
Fluvio-Marine landforms, etc.

In general, all these geomorphic landforms can be classified as

- Erosional
- Depositional
- Denudational and
- Structural.

EROSIONAL

River valleys - V shaped valley development starts from

Splash erosion ➔ sheet erosion ➔ Rill erosion ➔ Gullies ➔ V shaped valley

Gorges – active down cutting of valleys

Canyons – extended form of gorge

Waterfalls – Rapids, Cascades

Potholes

River terraces - Alluvium and gravels, flood plains

Meanders – U shaped valleys, sand bars, braided streams, point bar, broad flood plain

Dissected Plateau- Poor to moderate gw prospect

Highly dissected plateau, Mod. Diss. Plate.

Undissected plateau - Gwp – very poor

Mesa and Buttes- Poor gwp.

Peneplains- with low residual hills, monadnocks.

DEPOSITIONAL LANDFORMS

Floodplain - unconsolidated fuvial sediment subjected to periodic flooding – very good for gwp.

Alluvial plain - Very good gwp.

Younger alluvial plain

Older alluvial plain

Alluvial fan

Deltas

Valley fills

River sand

Ravines

Meander scar - remnants of highly sinuous, crescent Shaped palaeodrainage system, cur-off from the main channel.

Old meander

Palaeochannel

Backswamp, Marshy area, Natural levee - good gwp.

Pond/lake

Sea Beaches - developed by wave swash and backwash

Barrier-island coasts

Lagoons

Coral reef coast

Atoll

Marine terrace

GEOMOPRHIC LANDFORMS responsible for GROUNDWATER Occurrence

DENUDATIONAL LANDFORMS
Tectonic force building new landforms for denudation.
Pediment - Poor gwp.

Pediplain
Shallow weathered buried pediplain,
Med. WBPP and Deep WBPP - good gwp..
Denudational hill - mod. to poor gwp.
Residual hill - Poor gwp.

STRUCTURAL LANDFORMS
Escaprments - Poor gwp. to nil gwp.
Dip slope - - do -
Cuesta - - do -
Hogback - - do -
Structural hills - - do -.

GROUND WATER RECHARGE

RECHARGE APPROACH:

- Understanding of Aquifer Conditions.
- Evaluation of various controlling parameters.
  - Geological (Lithology & Structures)
  - Soil conditions / Characters
  - Slope
  - Land use / Land cover
- Site suitable mechanism for recharge.

TYPES OF RECHARGE:

- **Natural recharge**
- **Artificial recharge**


NATURAL RECHARGE

NATURAL RECHARGE:

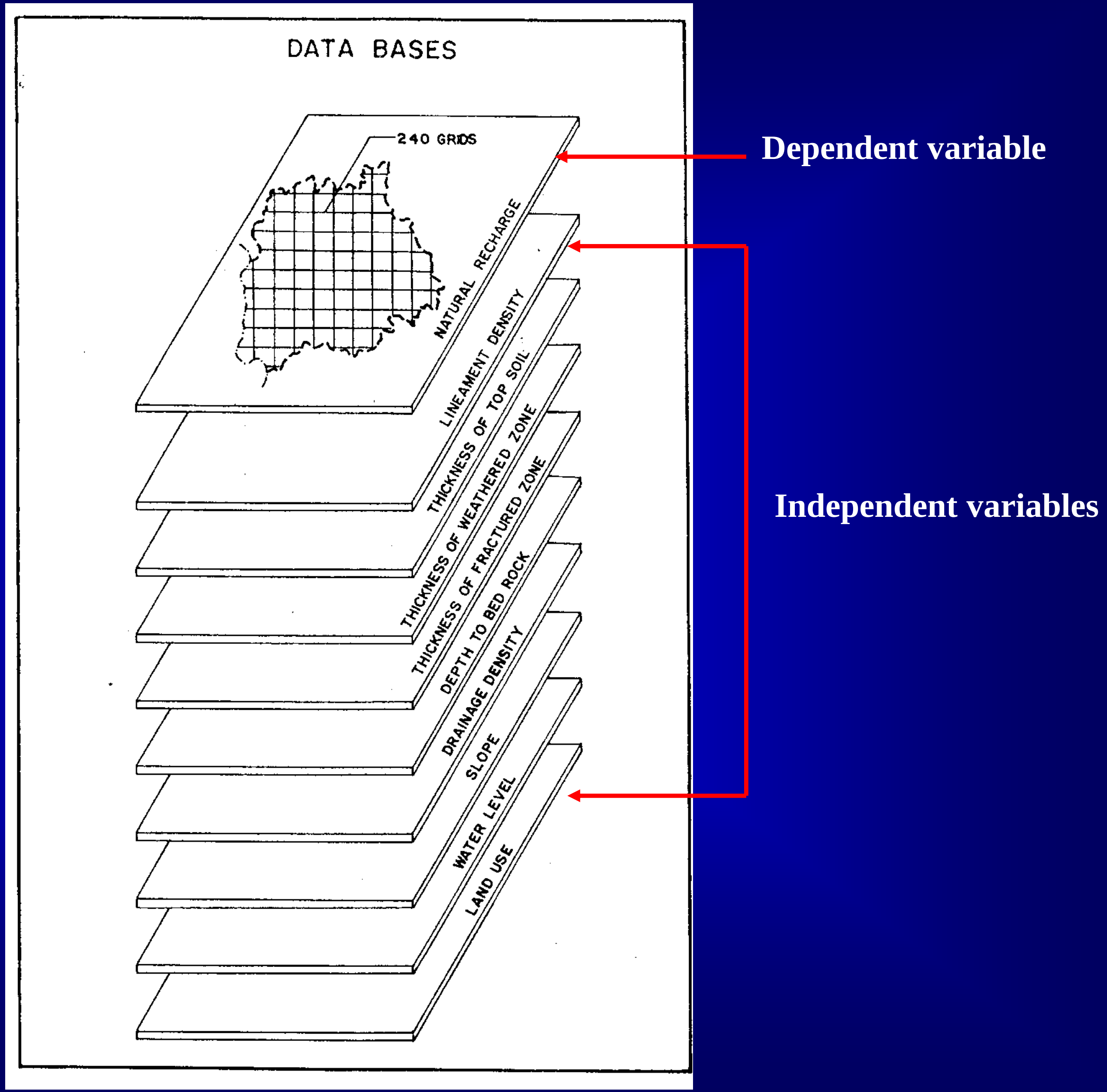
Variation in water level increase after the rain, i.e.,

- **Some area with 50cm raise**
- **Some other area with 5-10 meter raise**

So, we need to find the reasons for such variance

EVALUATION:

- Determination of Recharge pattern of the area from 30 years of pre- and post-monsoon water level data
- Preparation of various thematic maps on probable controlling parameters of natural recharge.
- Mathematical and Thematic integrated analysis for finding out the controlling parameters


DATA BASES
240 GRIDS
NATURAL RECHARGE
LINEAMENT DENSITY
THICKNESS OF TOP SOIL
THICKNESS OF WEATHERED ZONE
THICKNESS OF FRACTURED ZONE
DEPTH TO BED ROCK
DRAINAGE DENSITY
SLOPE
WATER LEVEL
LAND USE
Dependent variable
Independent variables

STPES INVOLVED

- Generate gridwise database
- Standardize the data – using linear stretching
- Calculate correlation matrix and then Eigen values – Factor scores – Factor loadings
- Filter out highly relevant variables
- Filter out the grids with high loadings and the database
- Calculate Regression values – build model
- By fitting the required value – identify the quantum of variables for improvement
- Iterate the same practice for other sets of values

NUMERICAL ANALYSIS

Generate Numerical Database for each theme - gridwise on:

Dependent variable:

- Natural recharge – in m

- Difference in water levels prior and after monsoons – Identify recharge and discharge areas

Independent variables

- Lineament Density – in km/64sq.km
- Thickness of Topsoil – in m
- Thickness of Weathered Zone – in m
- Thickness of Fractured Zone – in m
- Depth to Bedrock – in m
- Drainage Density – in km/64 sq.km
- Slope - in degrees
- Water level – in m and
- Land use / Land cover – by assigning NR capability based notional numerical grades and then values.

- Standardize the data, as the dependent as well as independent variables are in different units and varying range values. The formula used to standardize the data is:
- **Sd = (((X-Xmin)/(Xmax-Xmin))*99)+1**
- After standardizing, run correlation and factor analysis to derive Eigen Values and Eigen Vectors to understand the nature of relationship with Dep.Var.(NR) and other Ind.Var.
- Identify the factor loadings and then list out the factor scores – delineate the +ve signed grids so as to decide the **effective regions / grids** having considerable relations between NR and Ind.Variables
- Filter out the database for the effective areas and run Regression analysis.

- Buildup the numerical model
- Fit-in the regrouped data as input in the model to find out the quantum of Ind.Var. needed to attain required amount of NR.

Regression analysis to find out the:

- **Natural recharge domains according to the controlling parameters**
- **One to one mathematical relationship between natural recharge controlling Parameters and**
- **Optimization of controlling parameters for achieving efficient level of recharge during rainy season.**

Linear Regression Model

$$NR = 35.72938 + (0.1014 * TTS) - (0.5427 * TWZ) + (0.0851 * TFZ) - (0.3363 * DBR) - (0.0693 * SLP) - (0.4634 * WL)$$

Where, NR = Natural Recharge (in m); 35.72938 = Constant Coefficient A (Dependent Variable); Other values are Constant Coefficients of B1, B2, B3, B4, B5 & B6 (Independent Variables; they are: TTS = Thickness of Top Soil; TFZ=Thickness of Weathered Zone; TFZ=Thicknss of Fractured Zone; DBR=Depth to Bed Rock; SLP=Slope; WL= Water Level, respectively, with their +ve or –ve signs according to their relation with NR.

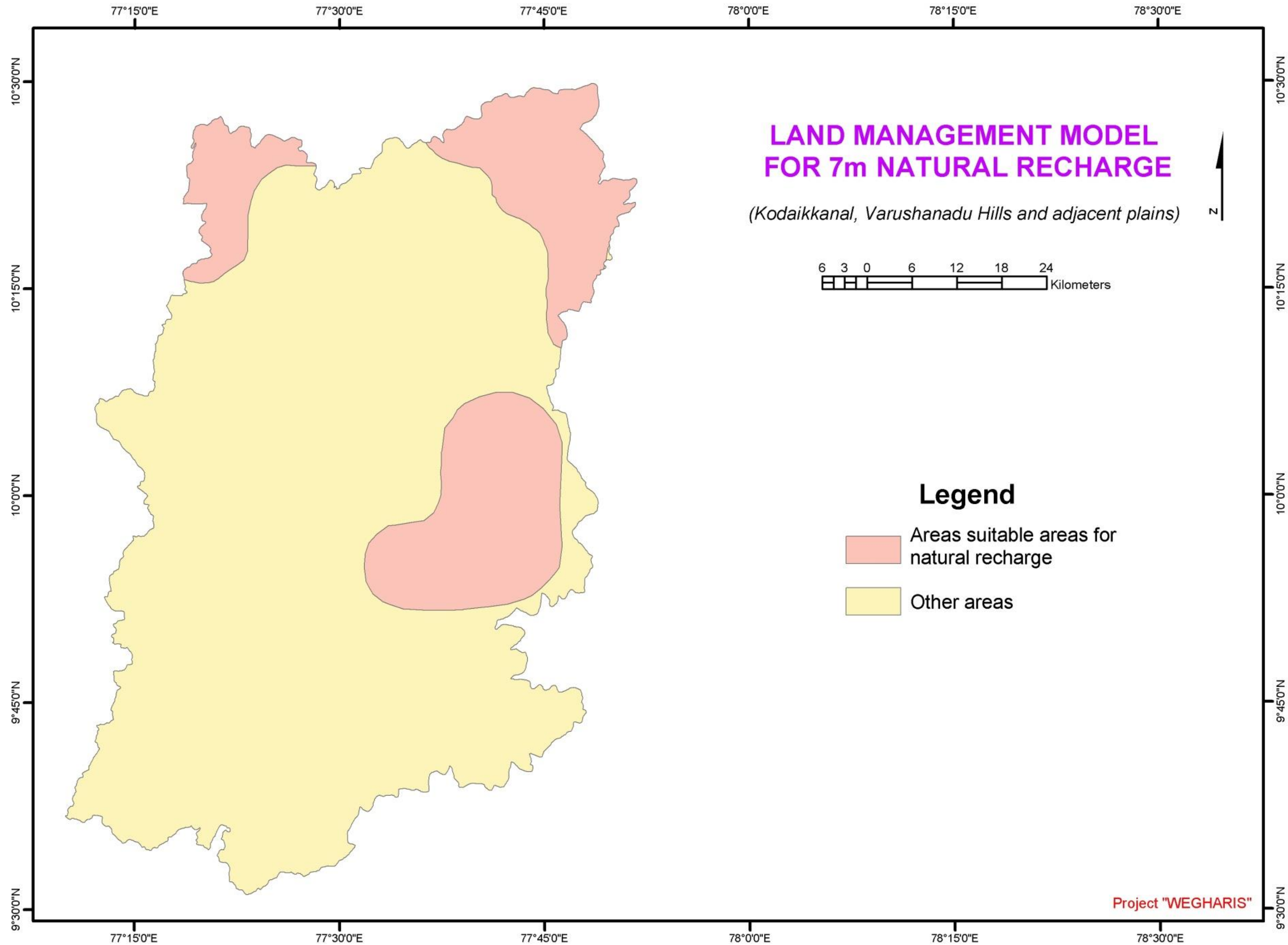
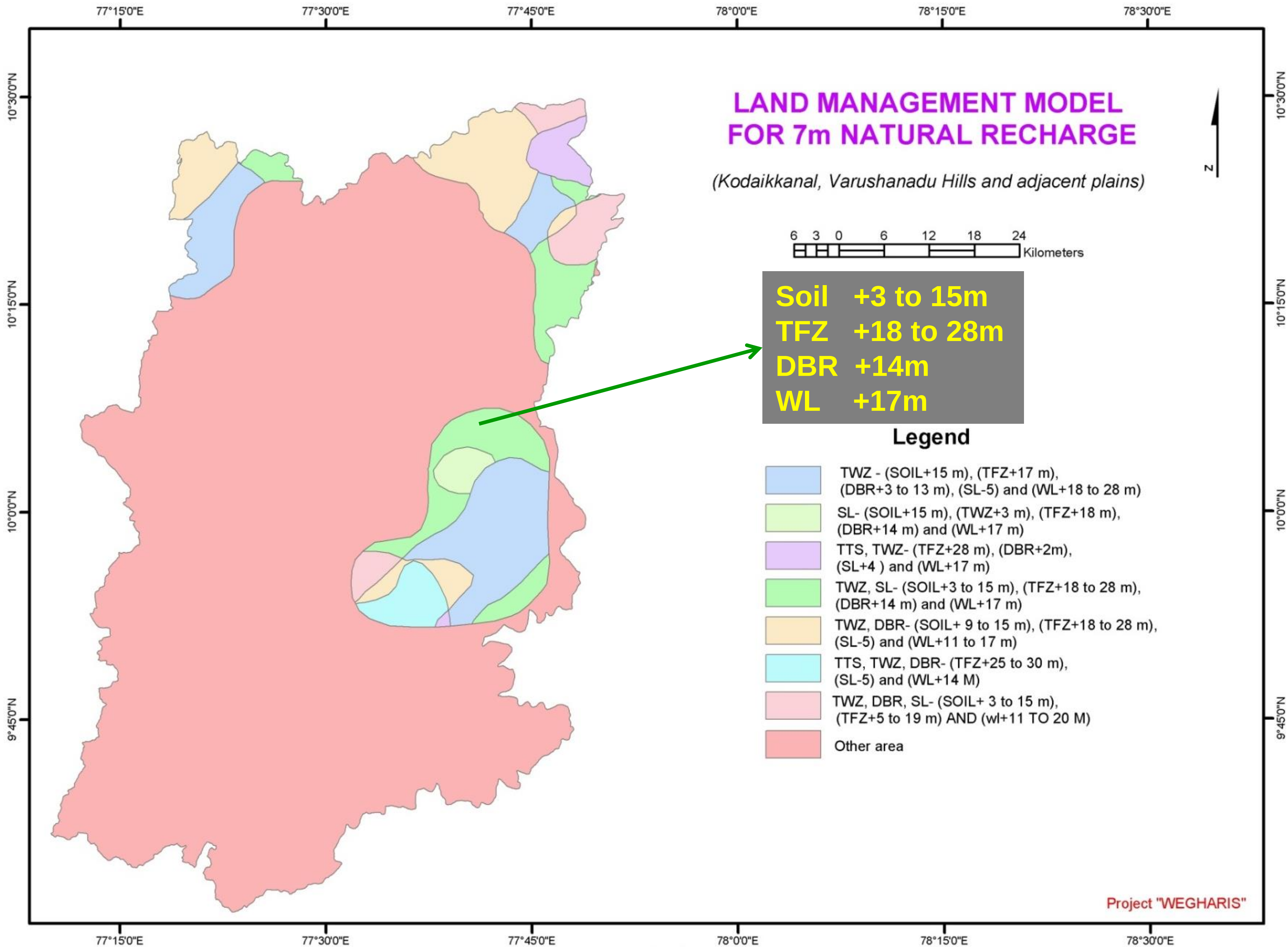

LAND MANAGEMENT MODEL
FOR 7m NATURAL RECHARGE
(Kodaikkanal, Varushanadu Hills and adjacent plains)
N
6 3 0 6 12 18 24
Kilometers
Legend
Areas suitable areas for natural recharge
Other areas
Project "WEGHARIS"
77°15'0"E
77°30'0"E
77°45'0"E
78°0'0"E
78°15'0"E
78°30'0"E
10°30'0"N
10°15'0"N
10°0'0"N
9°45'0"N
9°30'0"N

Fig. 4.1


LAND MANAGEMENT MODEL
FOR 7m NATURAL RECHARGE
(Kodaikkanal, Varushanadu Hills and adjacent plains)
6 3 0 6 12 18 24
Kilometers
N
Soil +3 to 15m
TFZ +18 to 28m
DBR +14m
WL +17m
Legend
TWZ - (SOIL+15 m), (TFZ+17 m), (DBR+3 to 13 m), (SL-5) and (WL+18 to 28 m)
SL- (SOIL+15 m), (TWZ+3 m), (TFZ+18 m), (DBR+14 m) and (WL+17 m)
TTS, TWZ- (TFZ+28 m), (DBR+2m), (SL+4) and (WL+17 m)
TWZ, SL- (SOIL+3 to 15 m), (TFZ+18 to 28 m), (DBR+14 m) and (WL+17 m)
TWZ, DBR- (SOIL+ 9 to 15 m), (TFZ+18 to 28 m), (SL-5) and (WL+11 to 17 m)
TTS, TWZ, DBR- (TFZ+25 to 30 m), (SL-5) and (WL+14 M)
TWZ, DBR, SL- (SOIL+ 3 to 15 m), (TFZ+5 to 19 m) AND (wl+11 TO 20 M)
Other area
Project "WEGHARIS"
77°15'0"E
77°30'0"E
77°45'0"E
78°0'0"E
78°15'0"E
78°30'0"E
10°30'0"N
10°15'0"N
10°0'0"N
9°45'0"N

ARTIFICIAL RECHARGE

ARTIFICIAL RECHARGE:

- To push maximum flood water into the aquifer system through appropriate site specific mechanism

- By constructing various structures, the storage and the infiltration increased which in turn recharge the ground water.

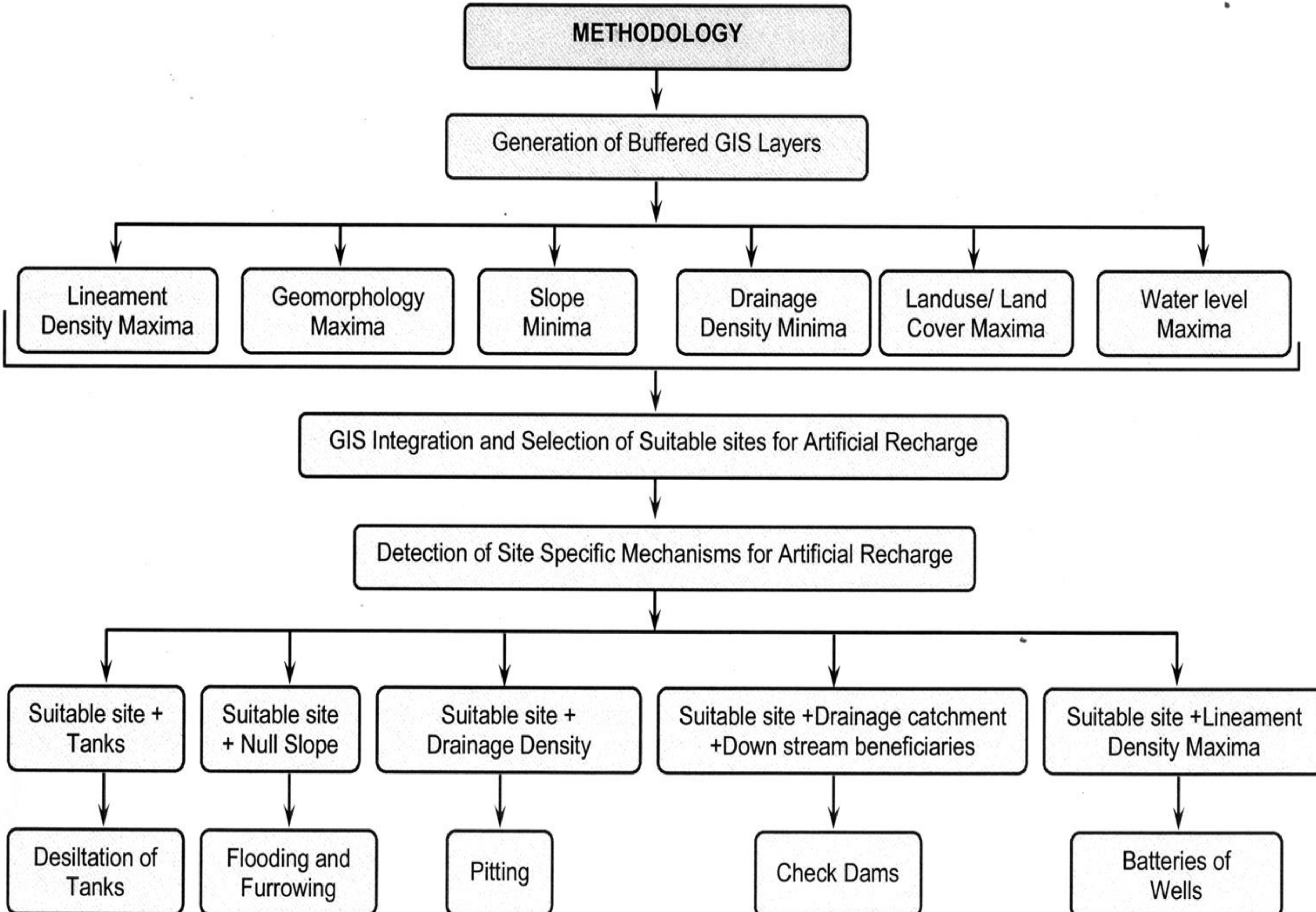
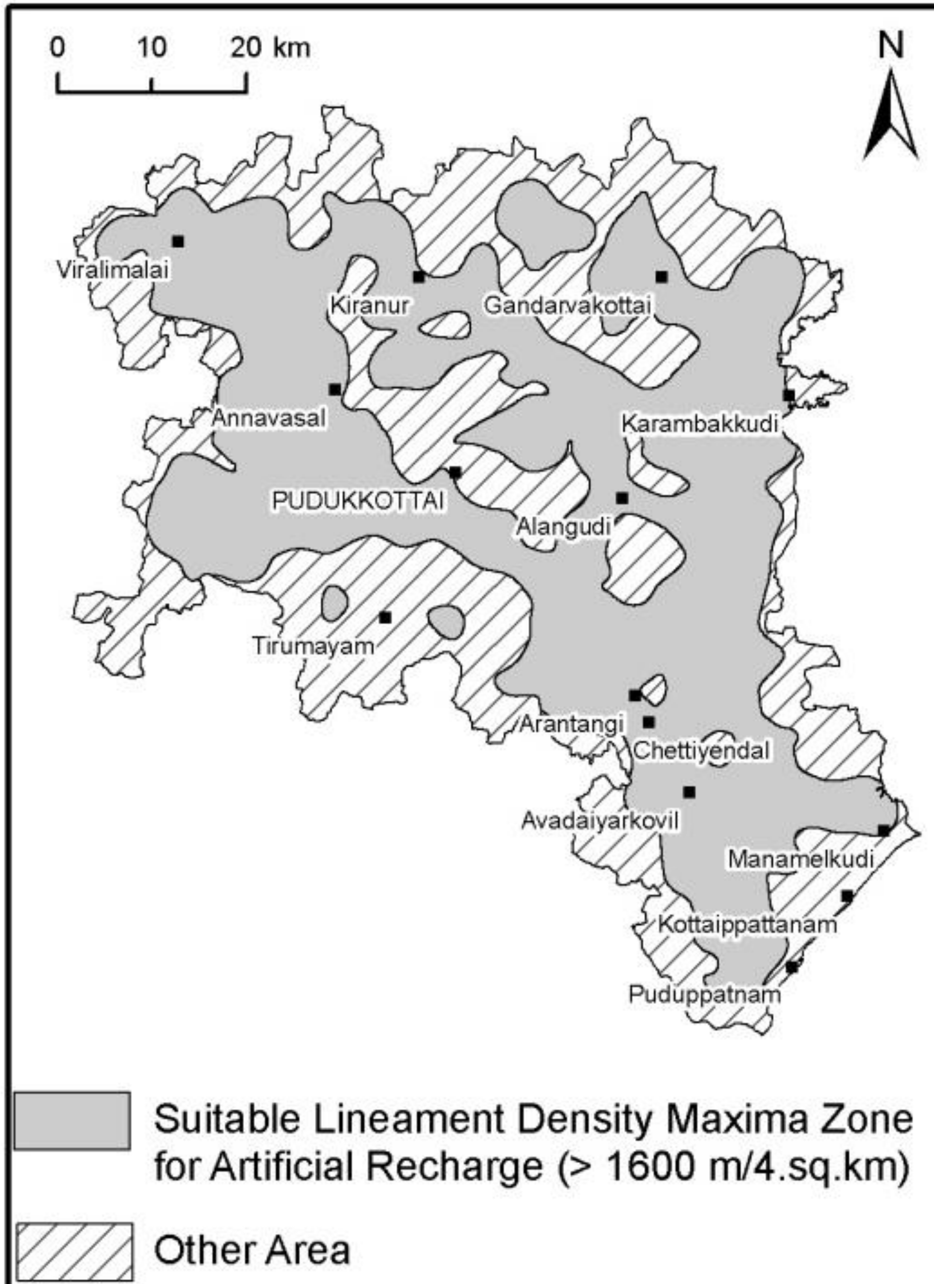


Fig. 6.36 Methodology – Site Selection and Mechanism Detection for Artificial Recharge



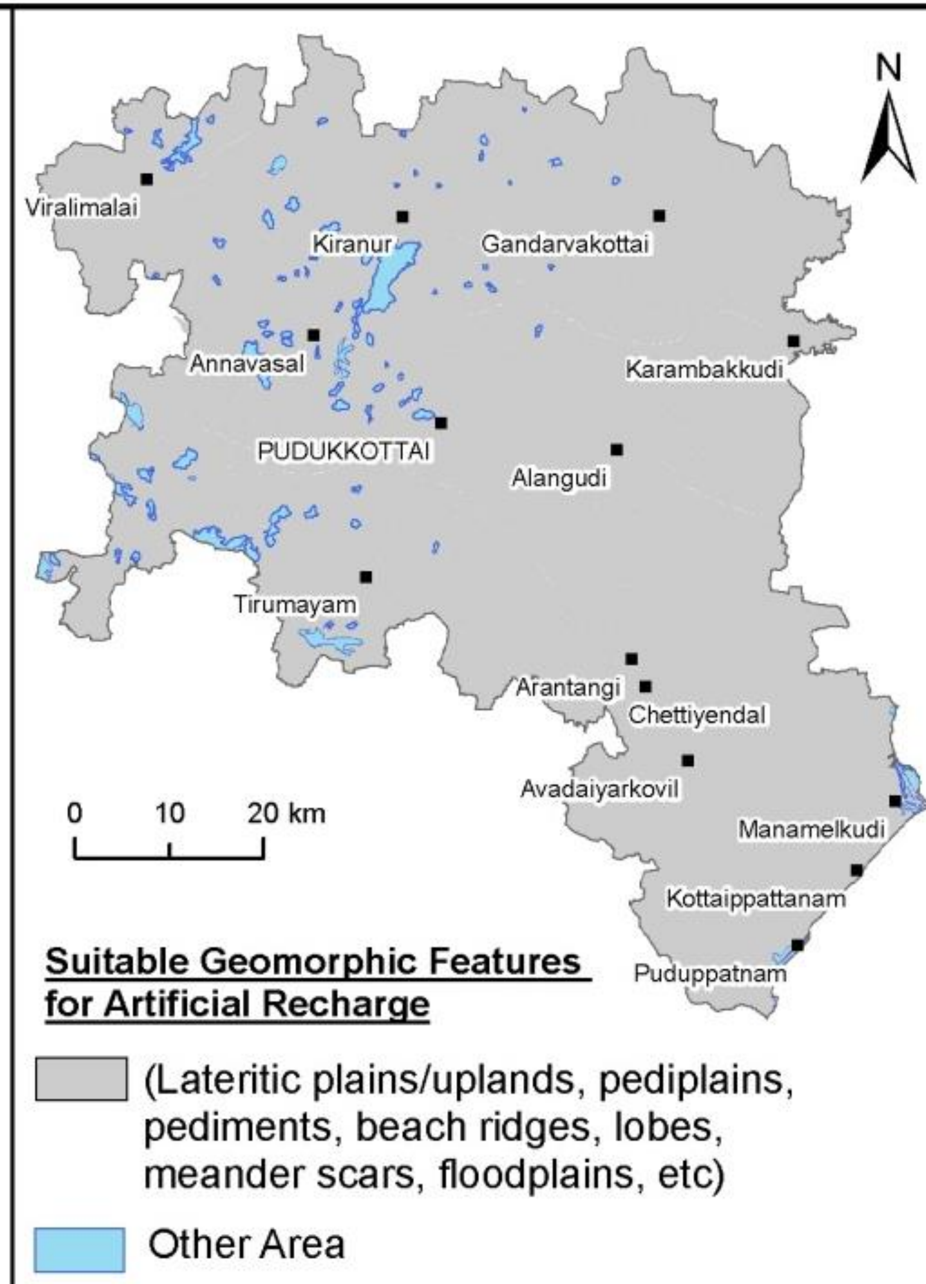


Fig.6.37 Lineament Density

Fig.6.38 Geomorphology

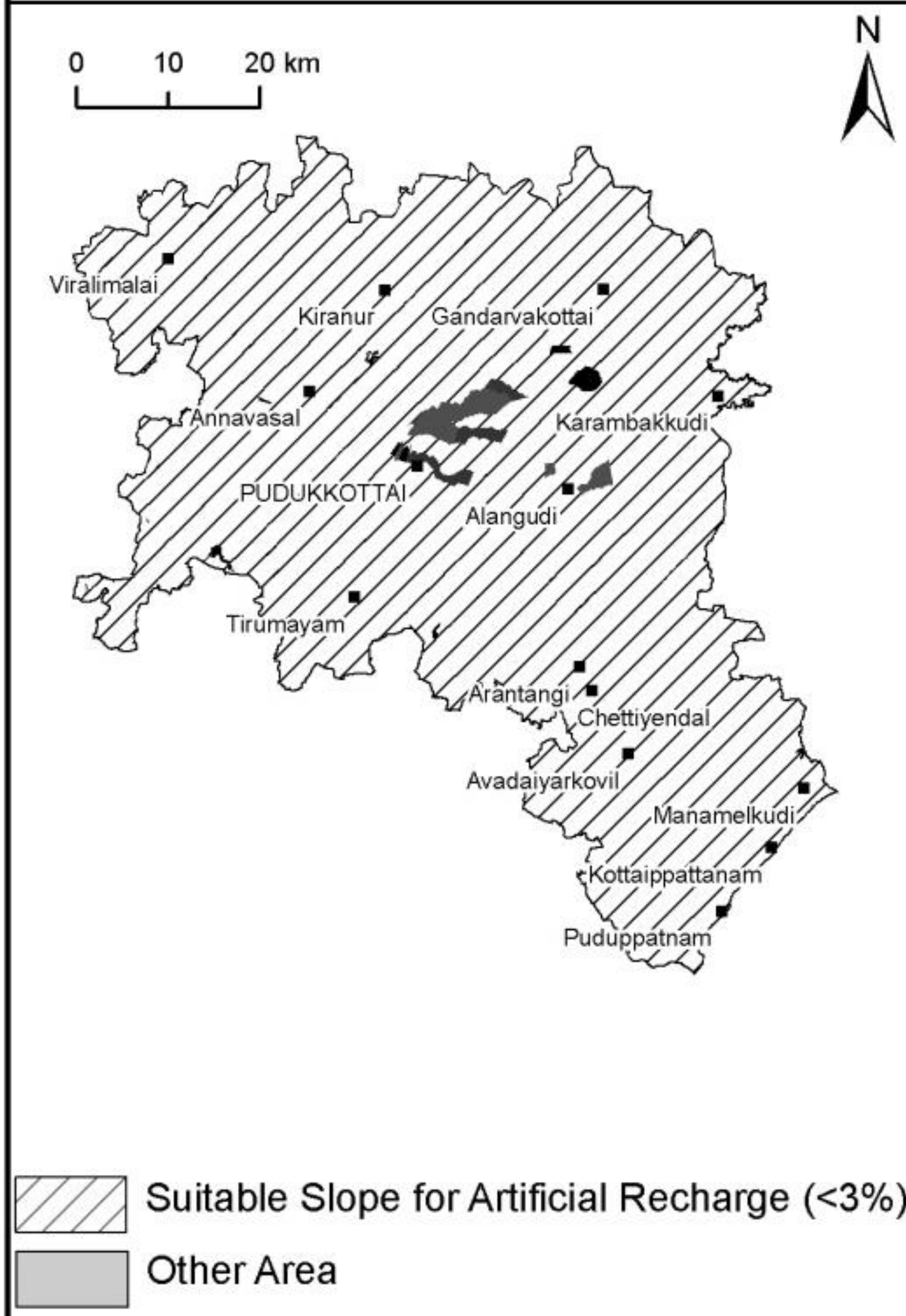


Fig.6.39 Slope

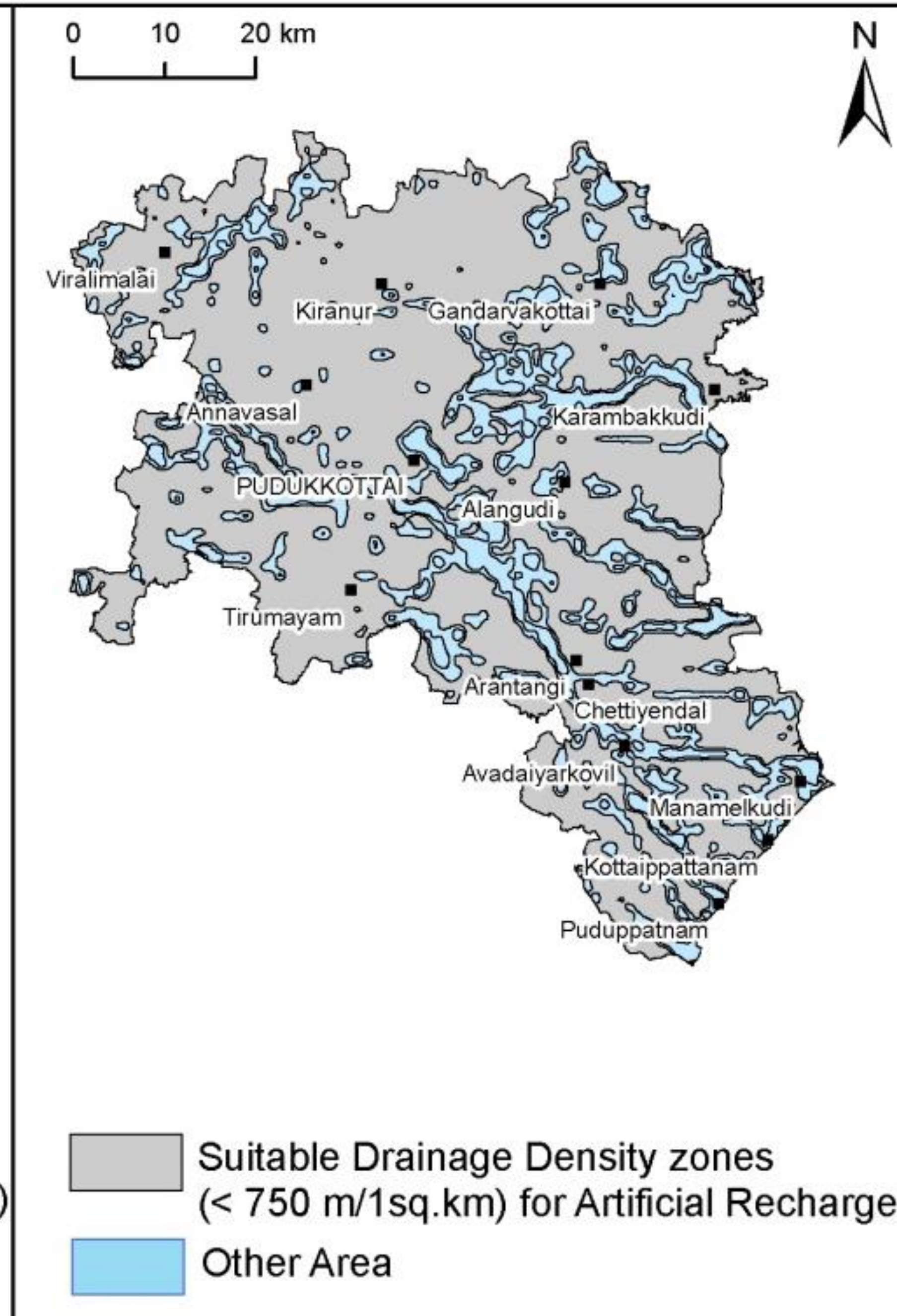


FIg.6.40 Drainage Density

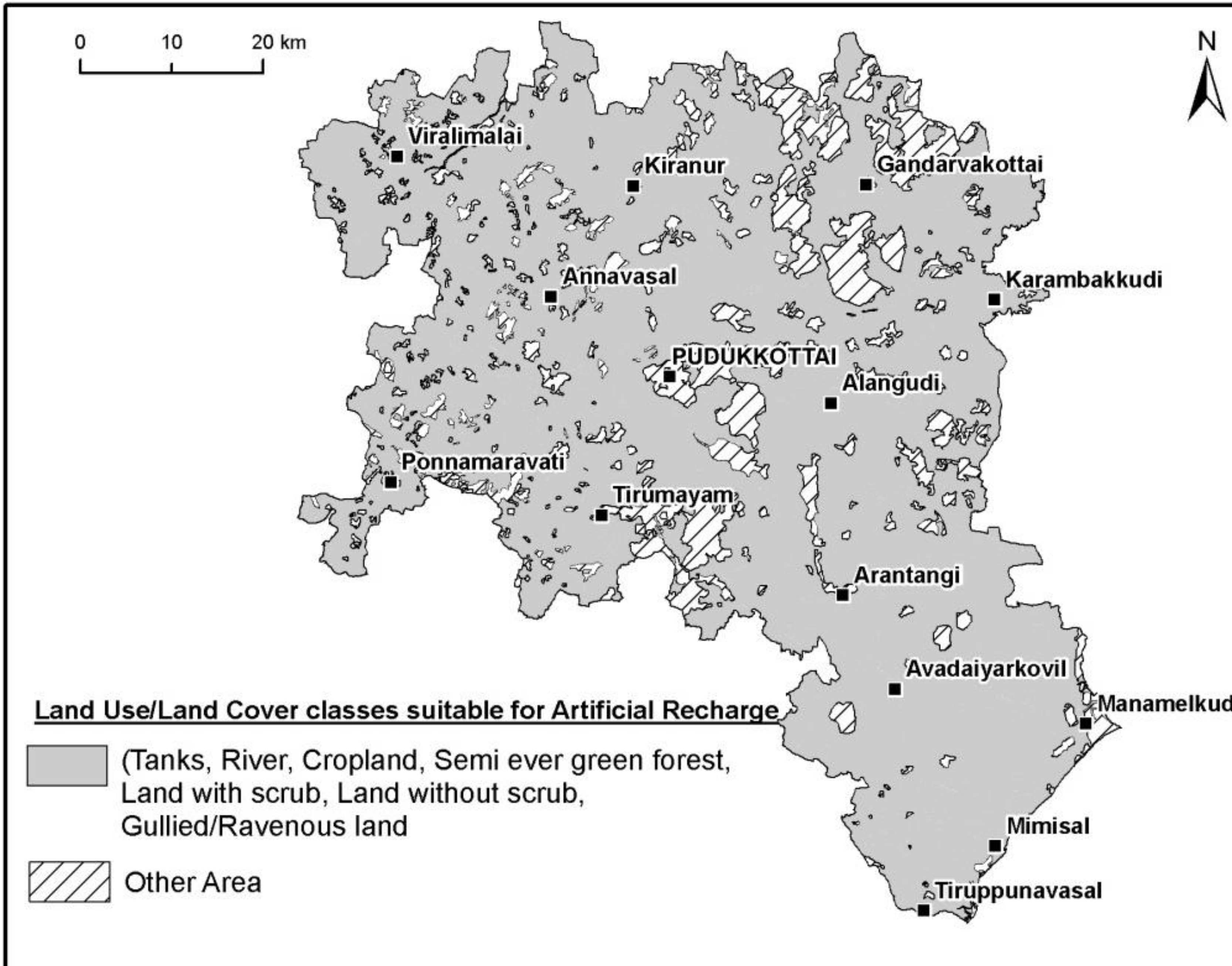


Fig.6.41 Land Use/Land Cover

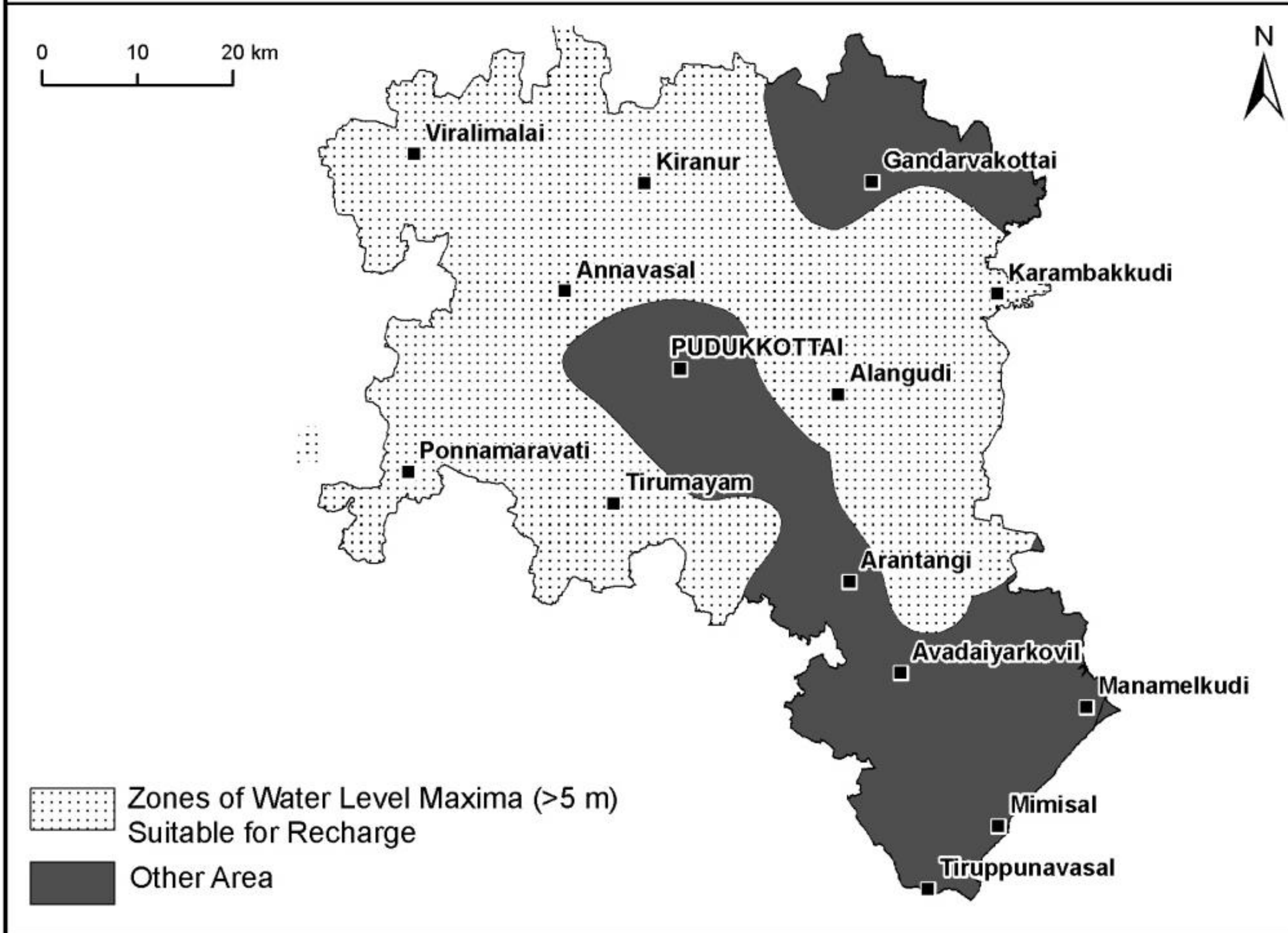


Fig. 6.42 Water Level

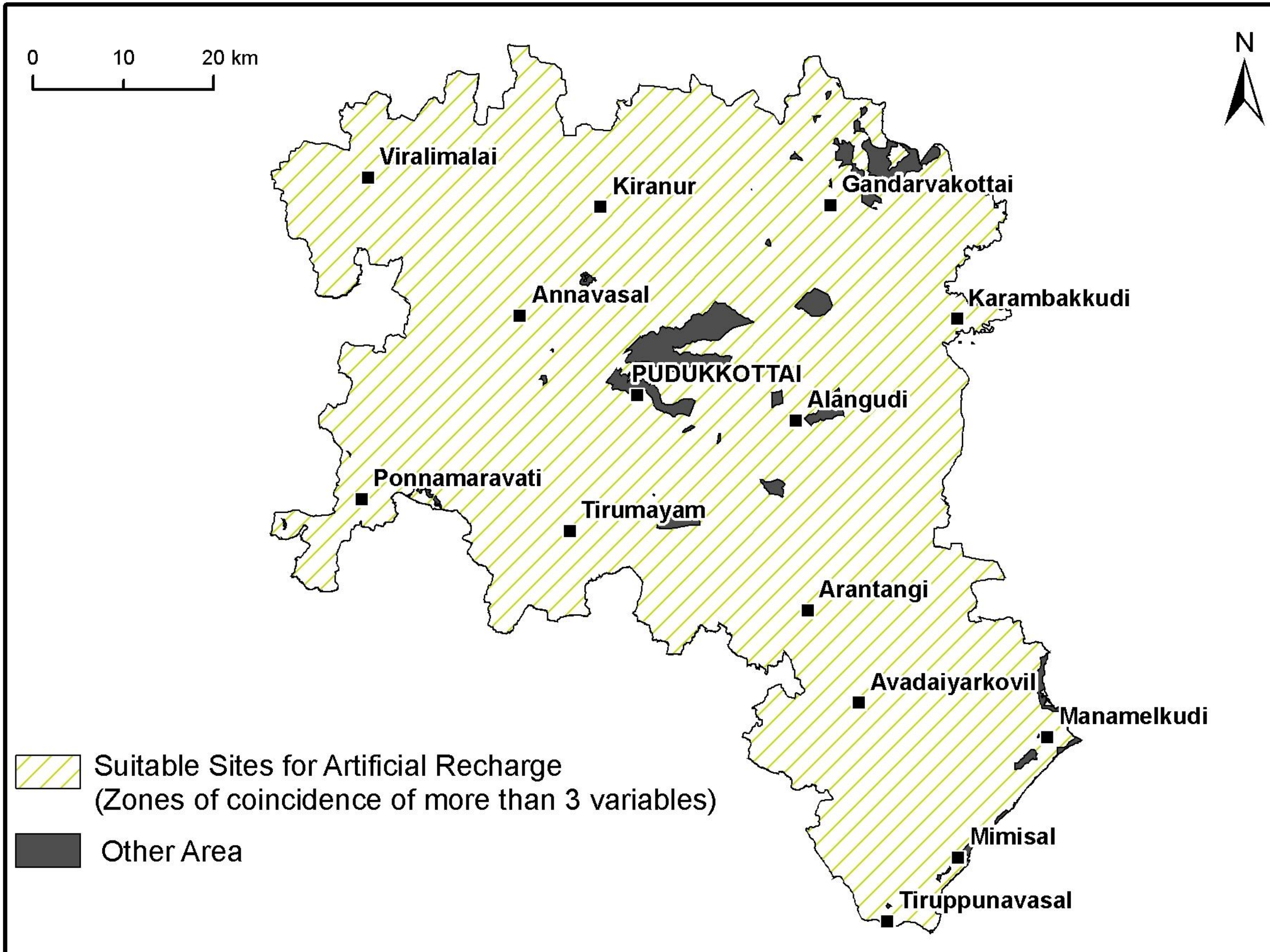


Fig.6.43 Suitable Sites for Artificial Recharge

Various types of structures:

- Desiltation of tanks
- Percolation ponds
- Dentritic furrowing
- Recharge Pitting
- En-echelon damming
- Induced recharge
- Batteries of wells, etc.

(f) Check dams

- On the 1st and 2nd order streams along the foot hill zones and in the areas with 0-5% slope

- Check dams were suggested in areas of drainage conversions within the sites selected for artificial recharge. In addition the availability of a down stream plain/down stream beneficiaries were considered. The sites so selected for check dam

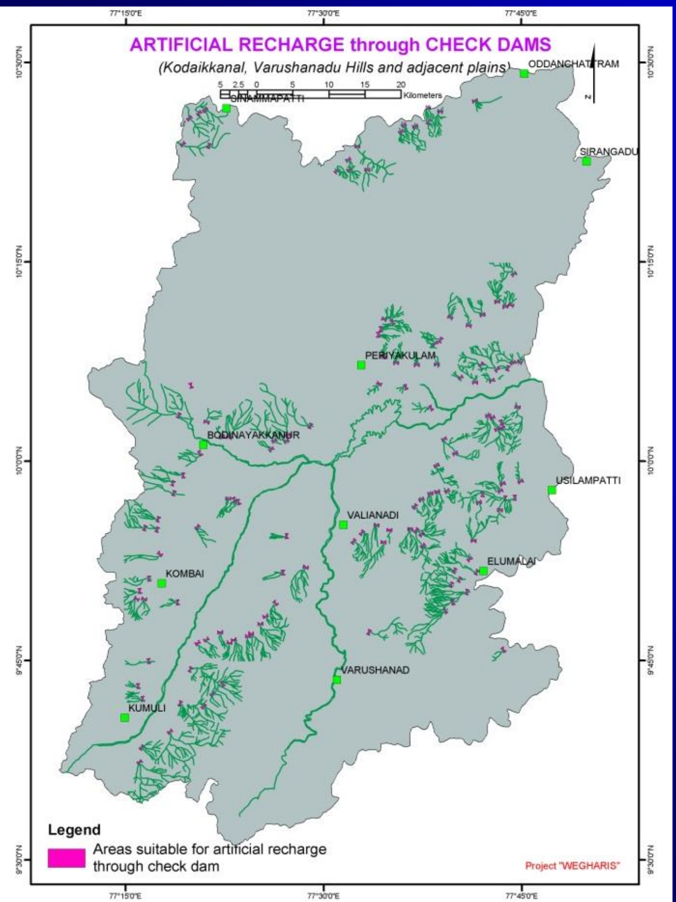


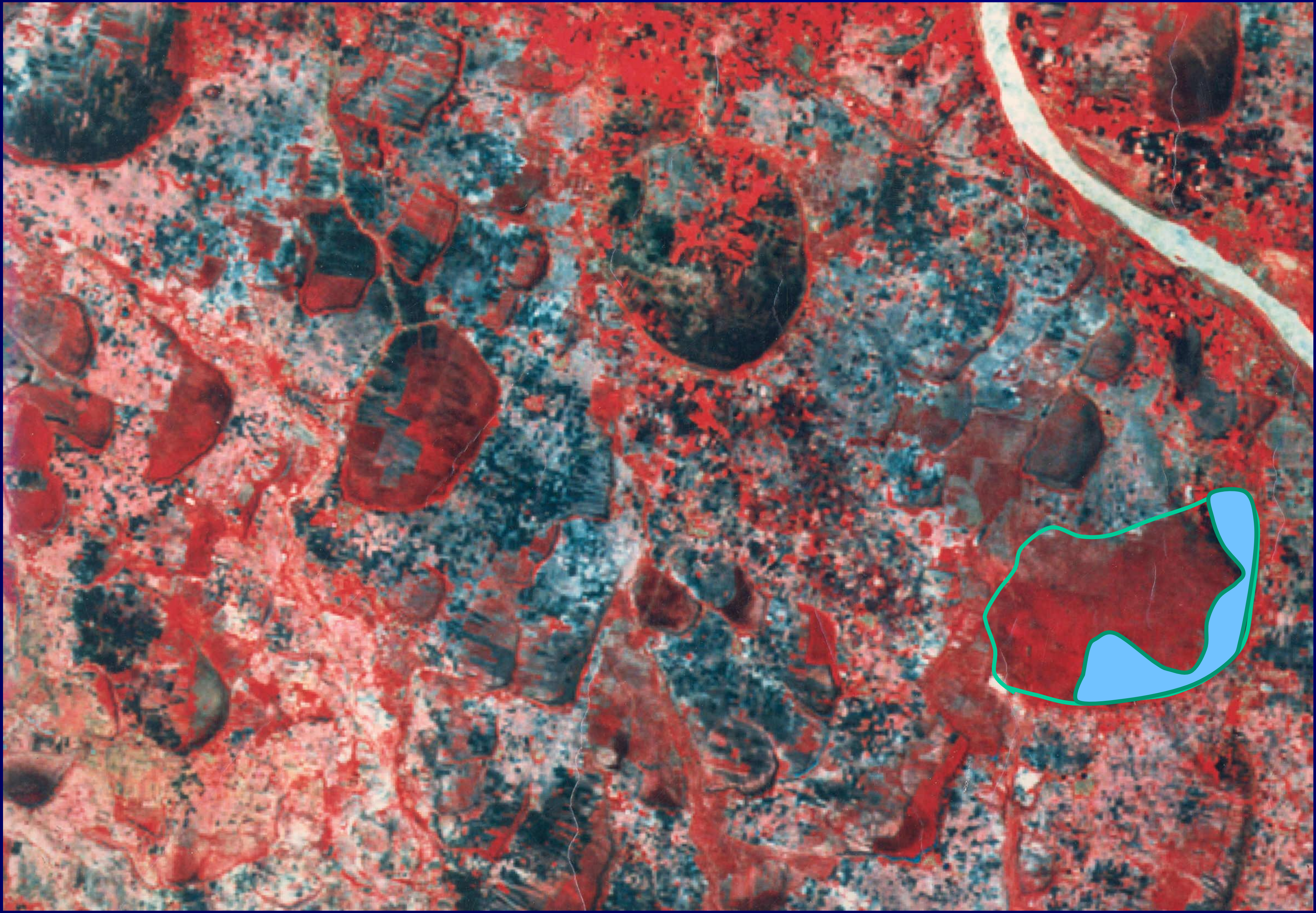
Fig. 4.8


Check dams


Desiltation of Tanks

- Over such GIS image showing “Areas suitable for artificial recharge” and the GIS image showing tanks was superposed and all the tanks which have fallen in this zone were suggested for desiltation. If these are desilted, they can act as very good tanks/ponds for artificial recharge.

DESILTATION OF TANKS



Desiltation of Tanks

PERCOLATION PONDING

Suitable areas:

- **Slope 1.5% and less**
- **Pervious soil**
- **Appropriate catchments**

In the areas of high recharge zone

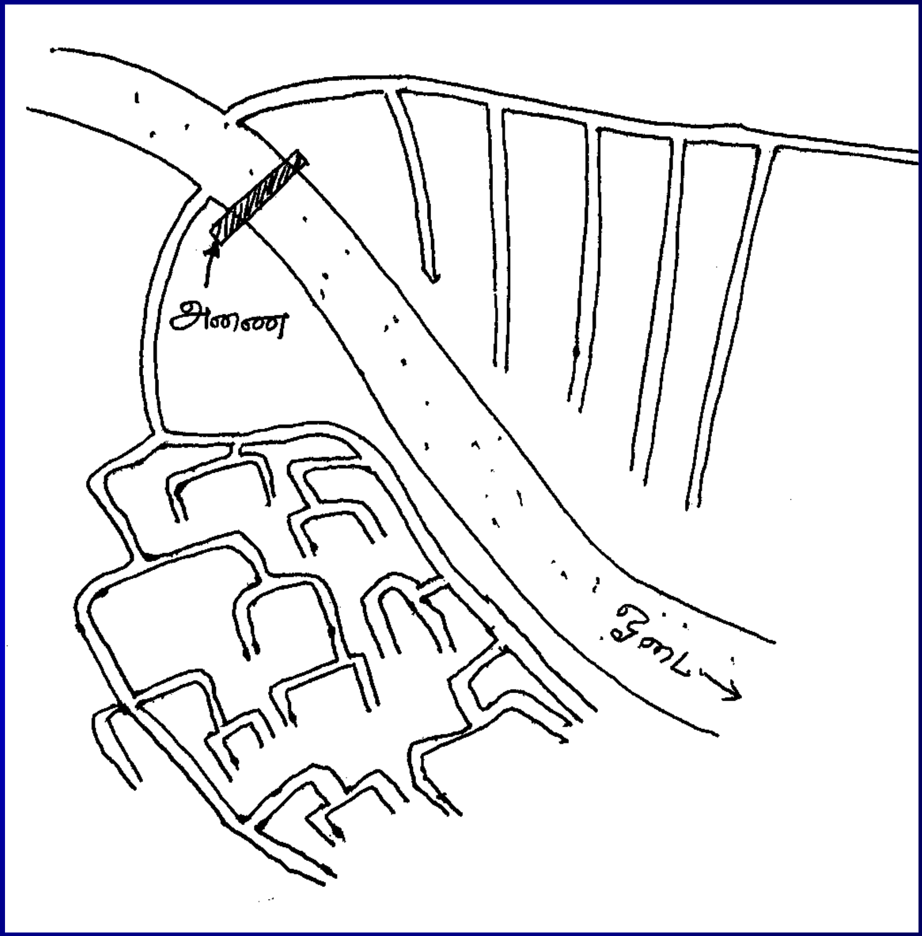
Percolation Ponds

Flooding & Furrowing

Suitable area:

- ❖ **Null slope**
- ❖ **Pervious soil at the surface**

In the areas of high recharge zone



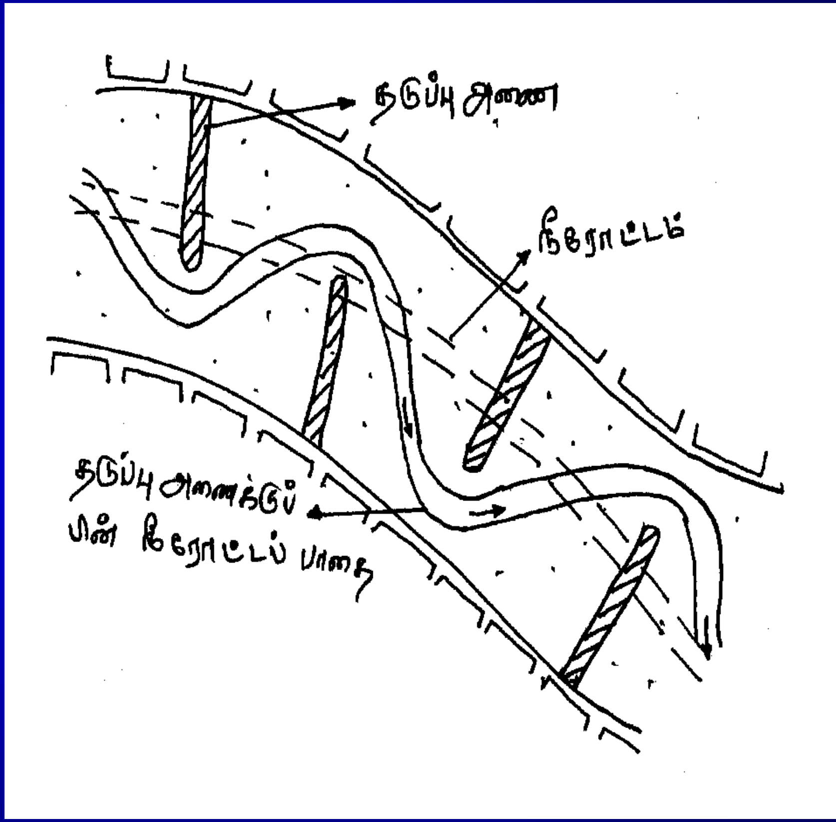
Flooding and Furrowing

EN-ECHELON DAMS:

Suitable areas:

- Straight drainage
- Wide span

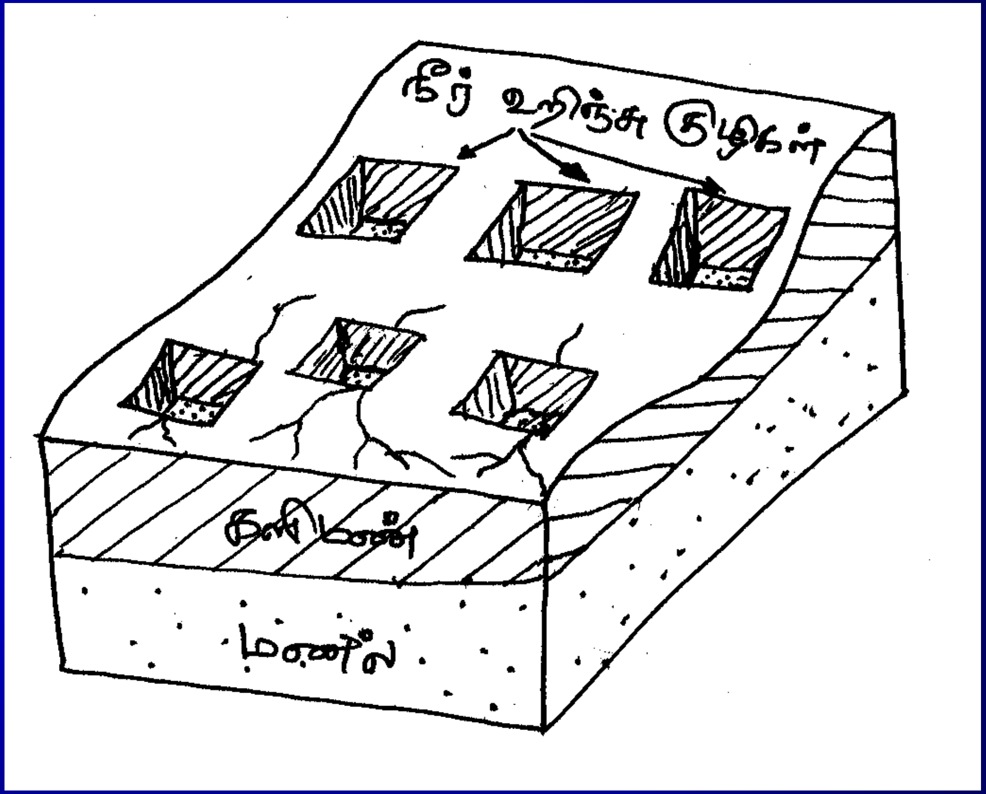
In the areas of high recharge zone



RECHARGE PITTING

In the areas where,

- Impervious layer at the surface and the pervious layer below
- More than mean drainage density area



(h) NALA BUND:

- On the 1^{st} to 4^{th} order streams flowing through the plains and valleys where acquisition of land for inundation of large areas is not possible.
- In this case, limited water will be stored in the river bed for some time which increases recharge

INDUCED RECHARGE

Suitable areas:

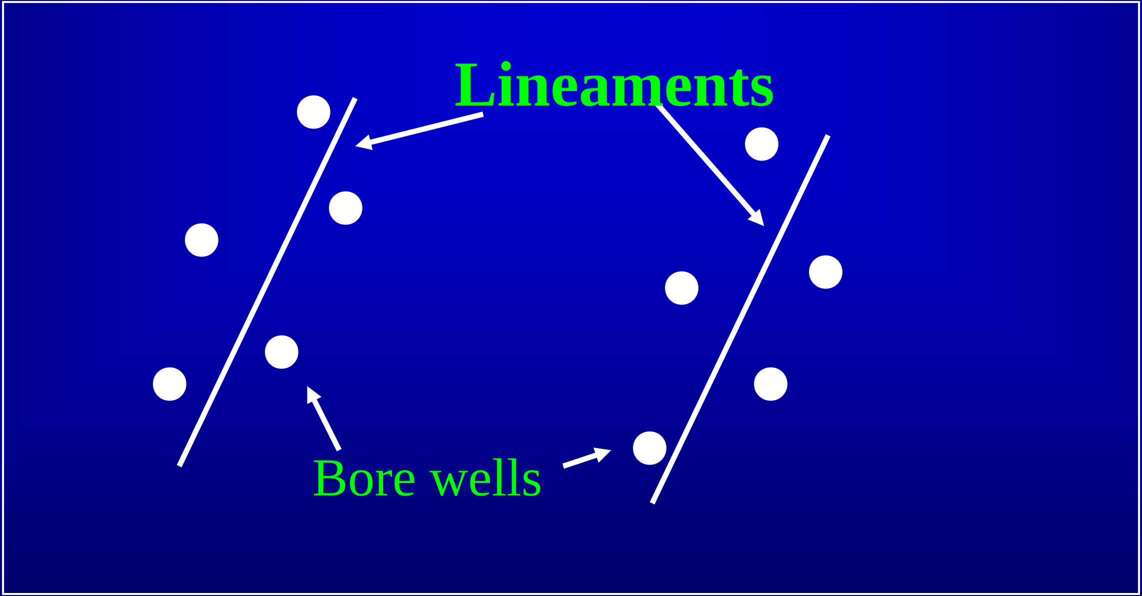
- **Water level minima Zone**
- **Drainage density maxima Zone**

In these zones pump the water through bore wells.

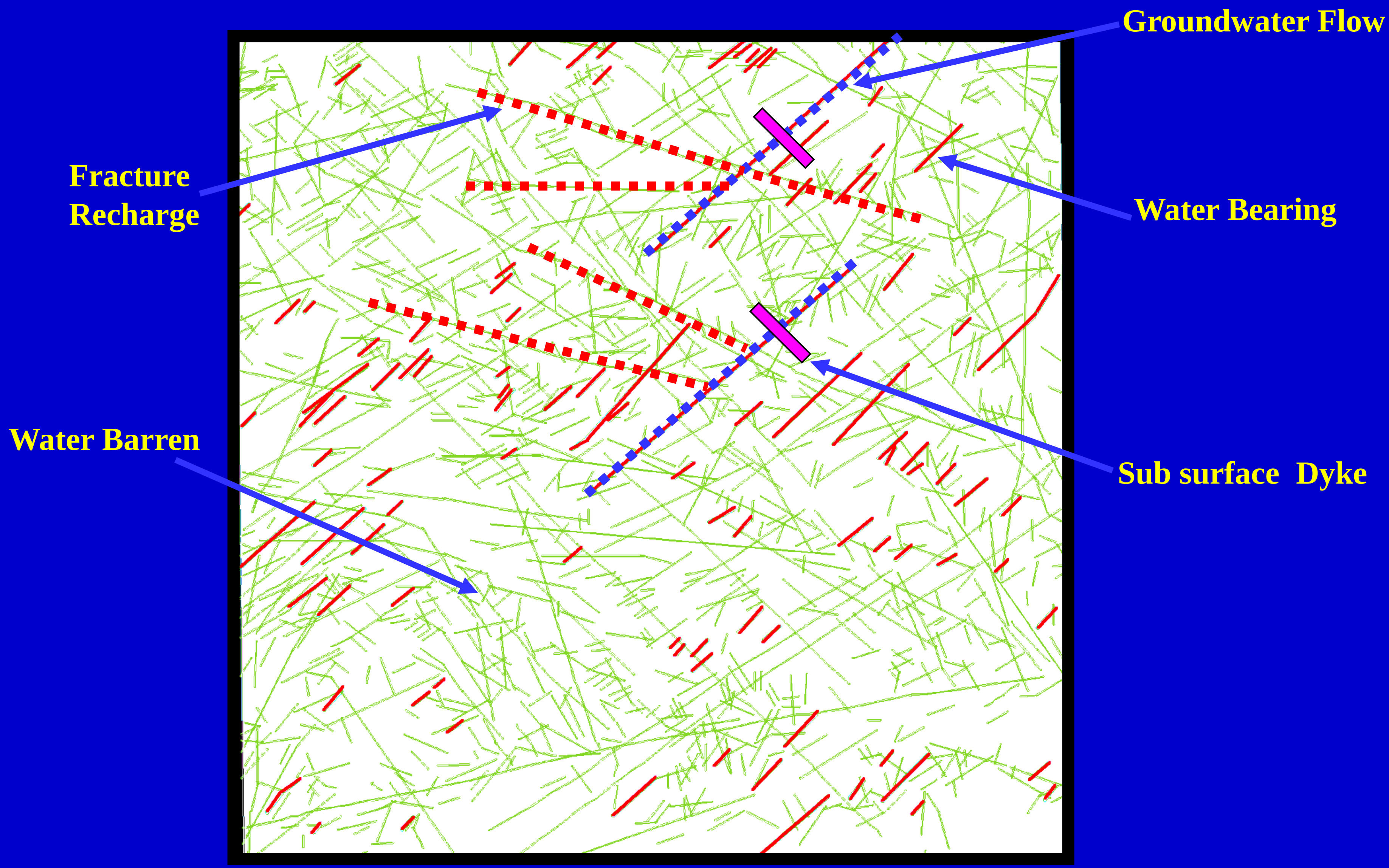
BATTERIES OF WELLS

In the areas of lineament density maxima zones

Bore wells on both sides of the fracture density maxima axes / major fractures



RECHARGE THROUGH FRACTURES



Quantification of Allowable Recharge

- Determination of size of the Aquifer / GW Reservoir / Container by Geophysical methods
- Calculation of Water level changes during a period of 30 – 50 years of pre- and post-monsoon seasons
- WR Budgetting – Estimation of available surface water resources for various purposes
- Quantification of available SW for Recharge of the container