GIS benyttet i analyser / Lavvannsprosjektet / småkraft

Astrid Voksø, NVE

GIS analyser I NVE – eksempler

- Beregne feltparametre for målestasjoner
- Lavvannskart for Norge
- Beregne vannkraftpotensialet for små kraftverk i Norge

Beregne feltparametre

Automatisk beregnet allerede med ArcInfo

- Hypsografisk kurve – DTEM 25*25 m
- Arealfordeling – arealdekkeflate fra N50 konvertert til GRID 25*25 meter.
  - Snaufjell alt over tregrensen

Nyutviklet metode -> manuelt til automatisk

- Effektiv sjøprosent
- Felt- og elvegradienter

Low flow index map for Norway

- Background
  - Calculate the common low flow , $Q_{clf,}$
    - Required information in
      - Decision-making concerning small hydro power plants
      - Water supply a.s.o
  - Low flow index is different discharges indicating how low discharge can be at a certain point

Normal discharge

Low discharge

Low flow index map for Norway

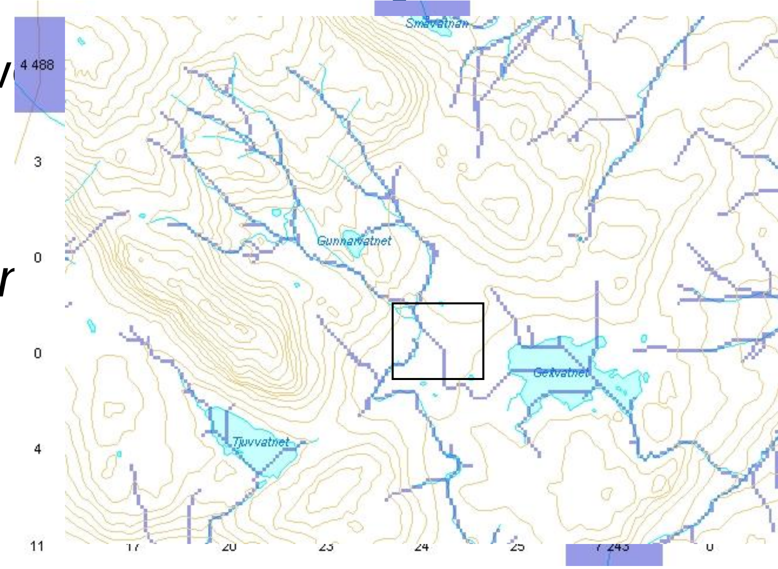
- Finding regression equations for homogenous regions in Norway at ungauged sites
- Establish a relationship between the common low flow and some catchment characteristics
  - Engeland et al. 2006
- GIS analyses defined for all the parameters using national datasets prepared or developed at NVE
- User interaction through a web-application towards a GIS server

Two main issues and a user interface

- From a random point on all rivers in Norway, generate a watershed with high accuracy catchment boundaries
  - The method for creating watersheds are standard in our GIS system (ArcGIS), but the result is depend on dataset used
- Calculate all input parameters to the regression model automatically using ArcGIS with Spatial Analyst as extension
  - A number of parameters had already an analyse design and automated
  - Develop dataset and analyses to be automated for the rest of the parameters
- User interface
  - The system should work on web using ArcGIS server

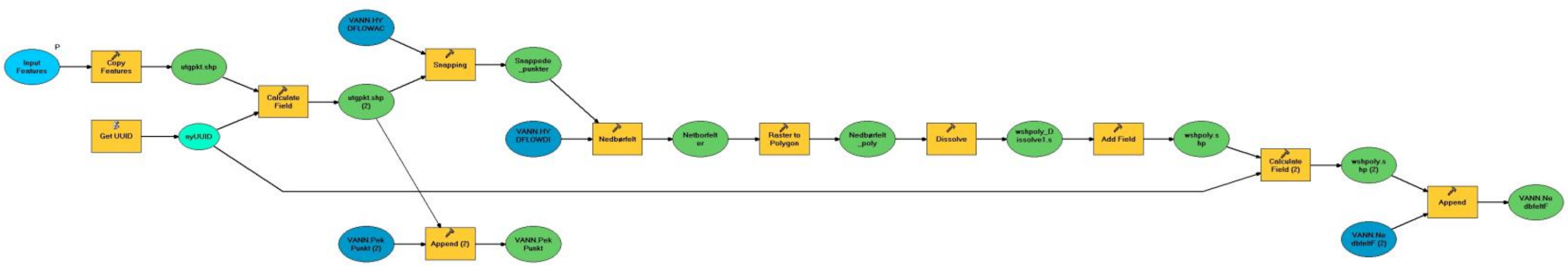
Calculate watershed from a point

- Require a flow accumulation grid derived from a terrain model with high resolution and quality
  - DTEM 25, adapt to hydrology
    → *Hydrological digital elevation model*
  - Topo2raster input parameters
    - Elevation points from DTEM25
    - Lake with elevation
    - River network – correct direction on lines
  - Create flow direction grid and flow accumulation grid
    - River network burned 30 meter into Hydro DTEM in advance
- Process is time-consuming because
  - River network correctness is crucial
  - Quality control is essential



Chose a point – generate watershed

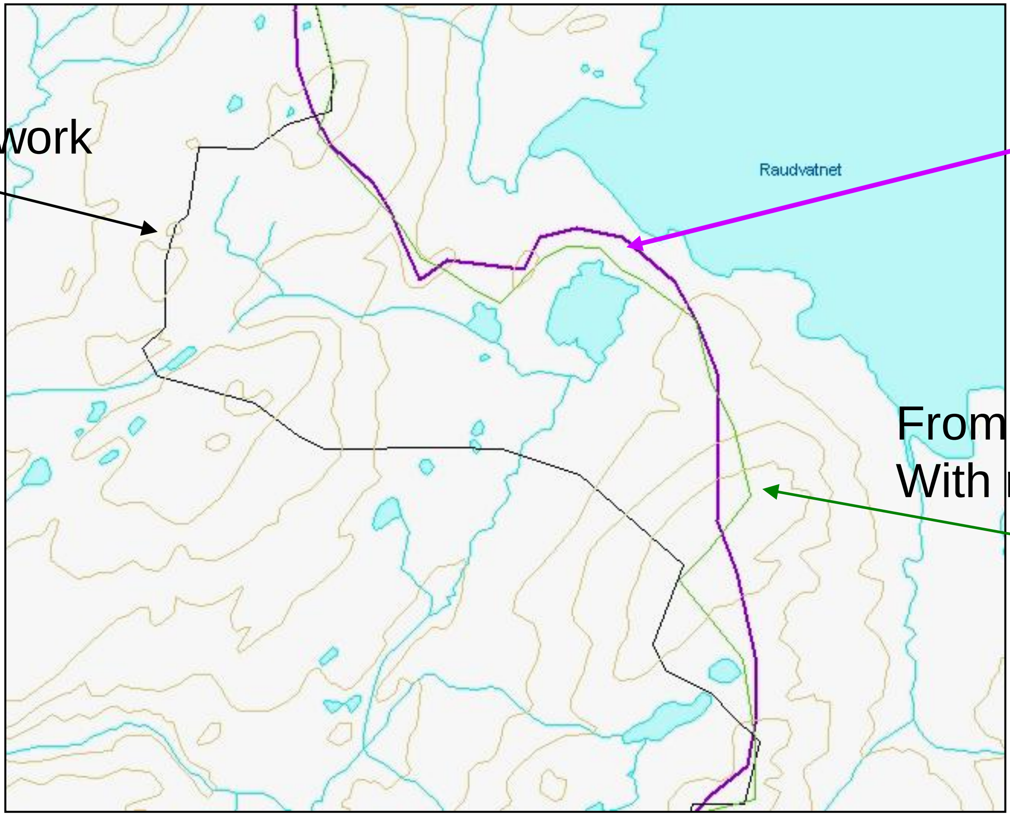
- Standard ArcGIS functionality
    - Spatial Analyst Tools – Hydrology
        - Uses 2 GRID: Flow Direction and Flow Accumulation



Comparing Flow accumulation grid

From DTEM25
Without river network

REGINE
waterdivide



From DTEM25
With river network

Chose a point – generate watershed

National datasets

- Required datasets developed at NVE
  - REGINE – watershed archive – 20.000 units
  - Lake database – all lakes > 2500 m² identified
  - River network –
    - Centre line of rivers and lakes connected to rivers in nodes. Lines have direction towards outlet in sea
  - Runoff map – GRID pixel size 1 x1 km² , each cell value is mean runoff from *1961-90 i mm. year*

The catchment characteristics included in the regression analysis

- Designed analyses
  - Catchment area (km^2)
  - Mean annual runoff ($l/s/km^2$) – runoff map of Norway
  - Maximum elevation (masl) – DTEM25
  - Minimum elevation (masl) – DTEM25
  - Elevation gradient
  - Landuse statistics – Landuse grid from scale 1:50.000
    - Urbanised areas (%)
    - Agriculture areas (%)
    - Forested areas (%)
    - Bogs (%)
    - Mountainous areas (%)
    - Lake percentage (%)

The catchment characteristics included in the regression analysis

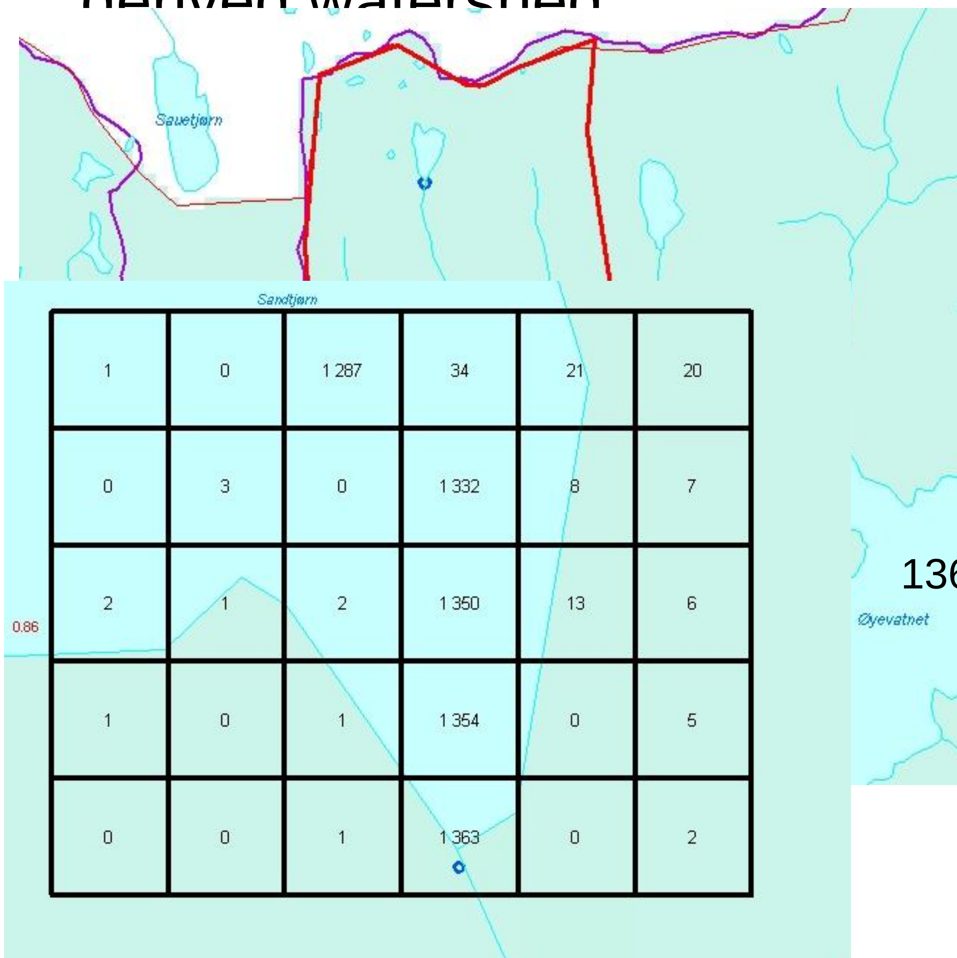
- Capture cell value of existing grid or using standard grid analyses on grids
  - Average annual temperature (^oC)
  - Average summer temperature (^oC)
  - Average winter temperature (^oC)
  - Average precipitation (mm)
  - Summer precipitation (mm)
  - Winter precipitation (mm)

The catchment characteristics included in the regression analysis

- Require pre-processing of data
  - Effective lake percentage (%)
- Require pre-processing of data and design
  - Length of main river (km)
  - River gradient (m/km)
  - River gradient excluding the 10 % lowest parts and the 15 % highest parts (1085 gradient) (m/km)
  - Catchment length
  - Catchment width
  - Catchment gradient

Calculate effective lake percentage

- Area of the derived watershed
- Lake area and catchment area for all lakes in the derived watershed



1	0	1 287	34	21	20
0	3	0	1 332	8	7
2	1	2	1 350	13	6
1	0	1	1 354	0	5
0	0	1	1 363	0	2

e flow accumulation grid

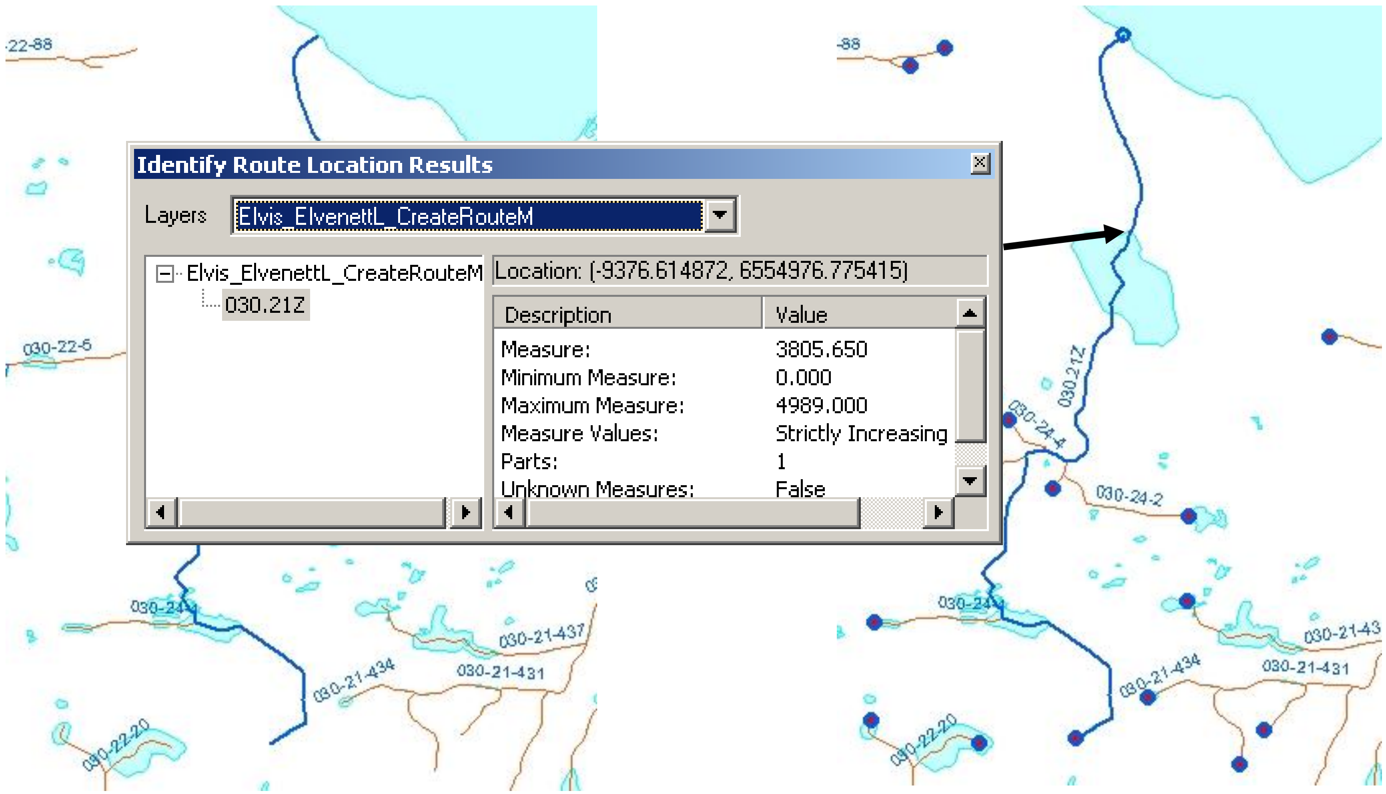
and area for each lake

lake

1363 * 625 / 1000000 = 0.85

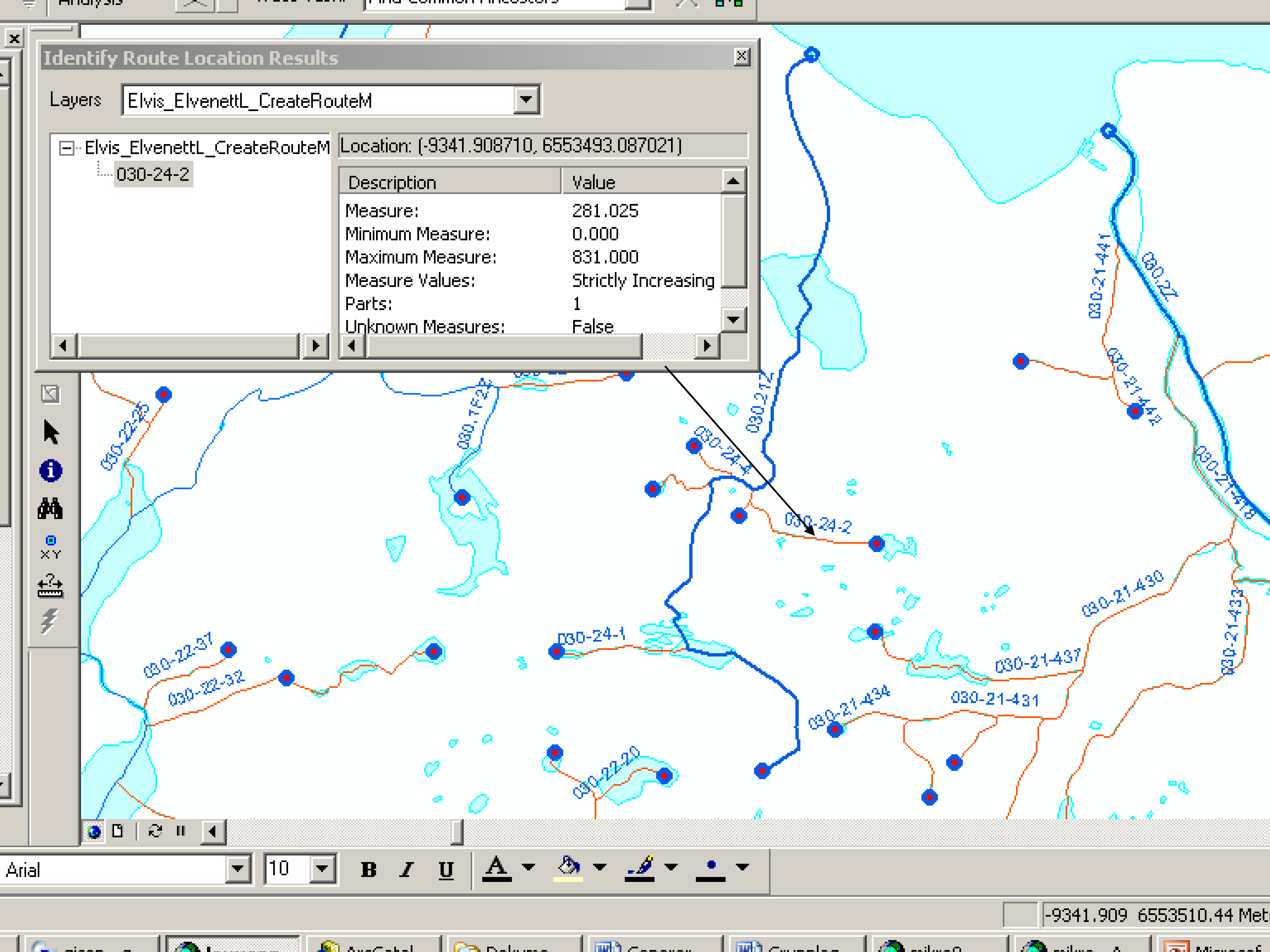
dArea)²

River length - and gradient



River in REGINE
REGINE-number - 024.15Z
Rest rivers – random number

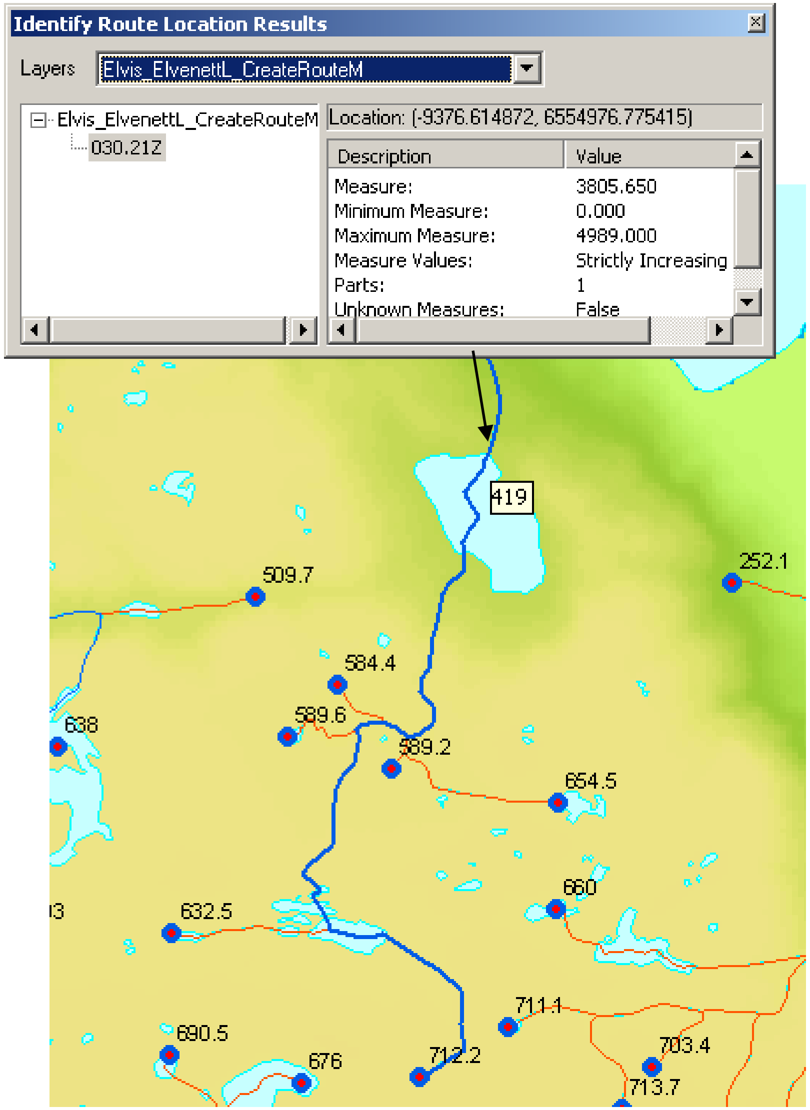
Create route
Calibrate route measure 0 at top
Length route measure at end



Identify Route Location Results
Layers
Elvis_ElvenettL_CreateRouteM
Elvis_ElvenettL_CreateRouteM
030-24-2
Location: (-9341.908710, 6553493.087021)
Description
Value
Measure:
281.025
Minimum Measure:
0.000
Maximum Measure:
831.000
Measure Values:
Strictly Increasing
Parts:
1
Unknown Measures:
False
030-24-2
030-24-1
030-24-4
030-21-430
030-21-437
030-21-431
030-21-434
030-21-441
030-22-37
030-22-32
030-22-20
030-22
X Y
Arial
10
B
I
U
-9341.909 6553510.44

River gradients

- Cell value from DTEM is the chosen points elevation
- Top of each river are identified with route name and elevation is calculated from the DTEM



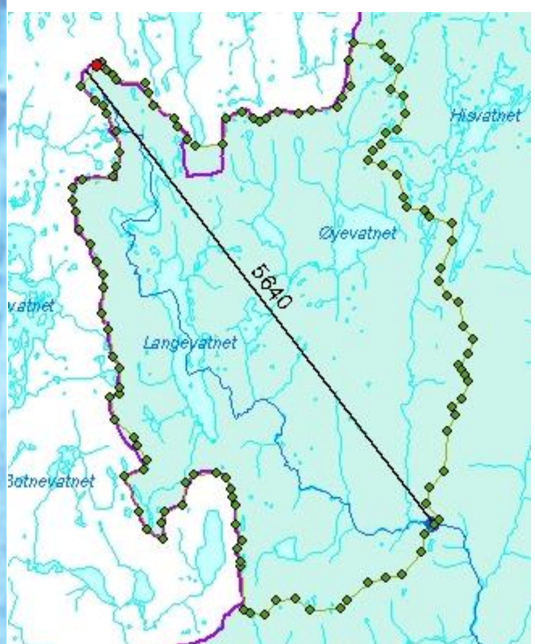
$S_T = (712.2 – 419) / 3.8 = 77$

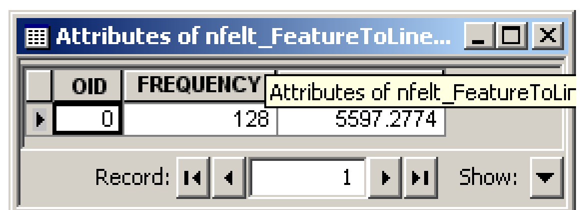
- 1085 gradient) (m/km)

River gradient excluding the 10 % lowest parts and the 15 % highest parts (m/km)

River - and catchment length

- **River length** = distance to top of river from your point
  - measure at the chosen point
- **Catchment length** = distance from chosen point to most remote point on the watershed divide
  - Change watershed divide from line to points and measure the distance from all points to the chosen point. Use the point with largest distance





User interface

- Web-application
- Map - and application tools
  - ArcSDE
  - ArcGIS Server
  - ArcIMS

- Parameters from GIS are captured using web-services
- Regression models are defined in a windows application

Conclusion

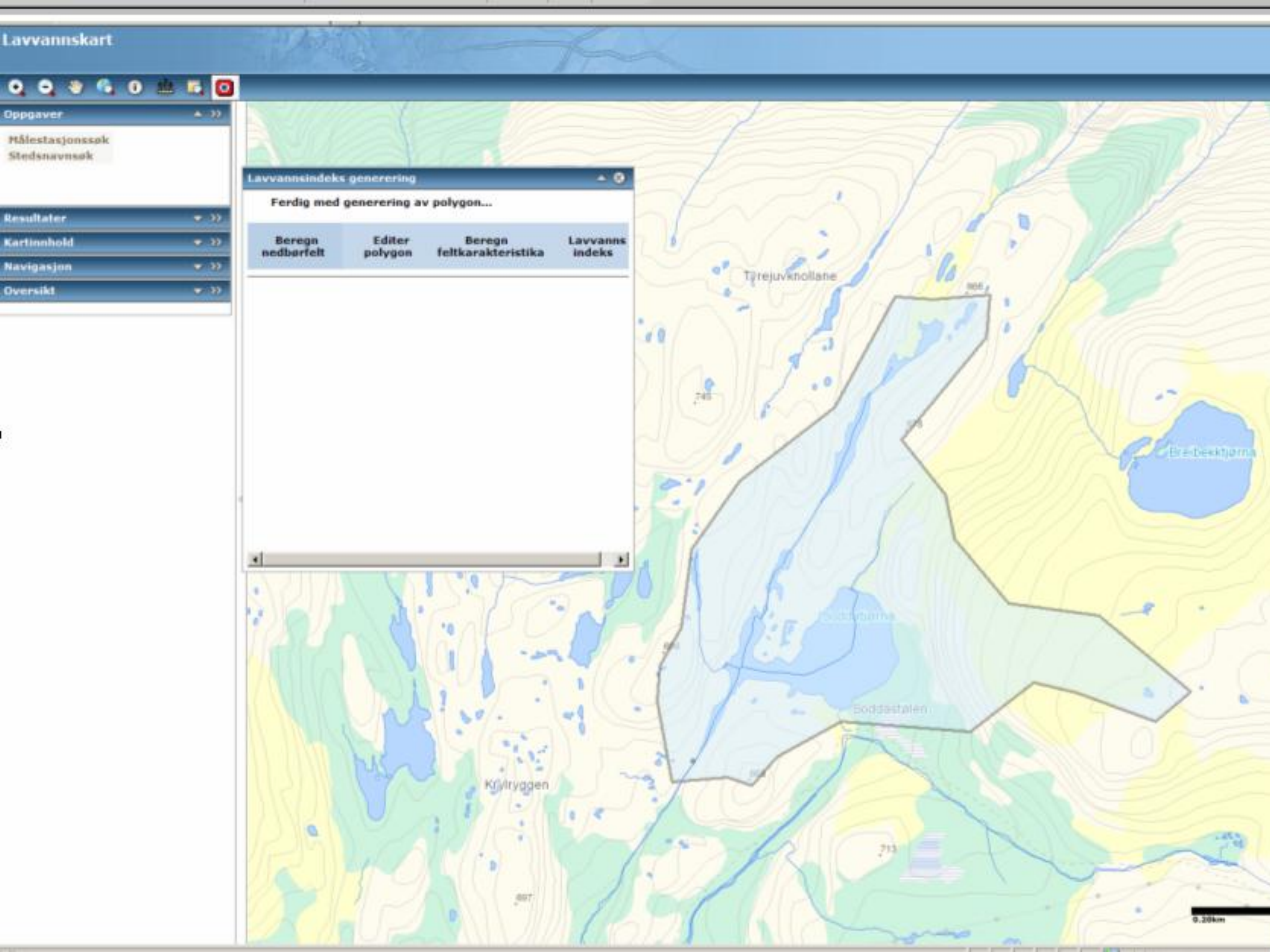
- The results of the GIS analyses are very good
  - Require a number of national datasets
  - Creating flowdirection and flowaccumulaton with high accuracy enable us to generate watersheds to points and lakes
    - Require quality check of river network
  - River network transform to routes with zero measure at top

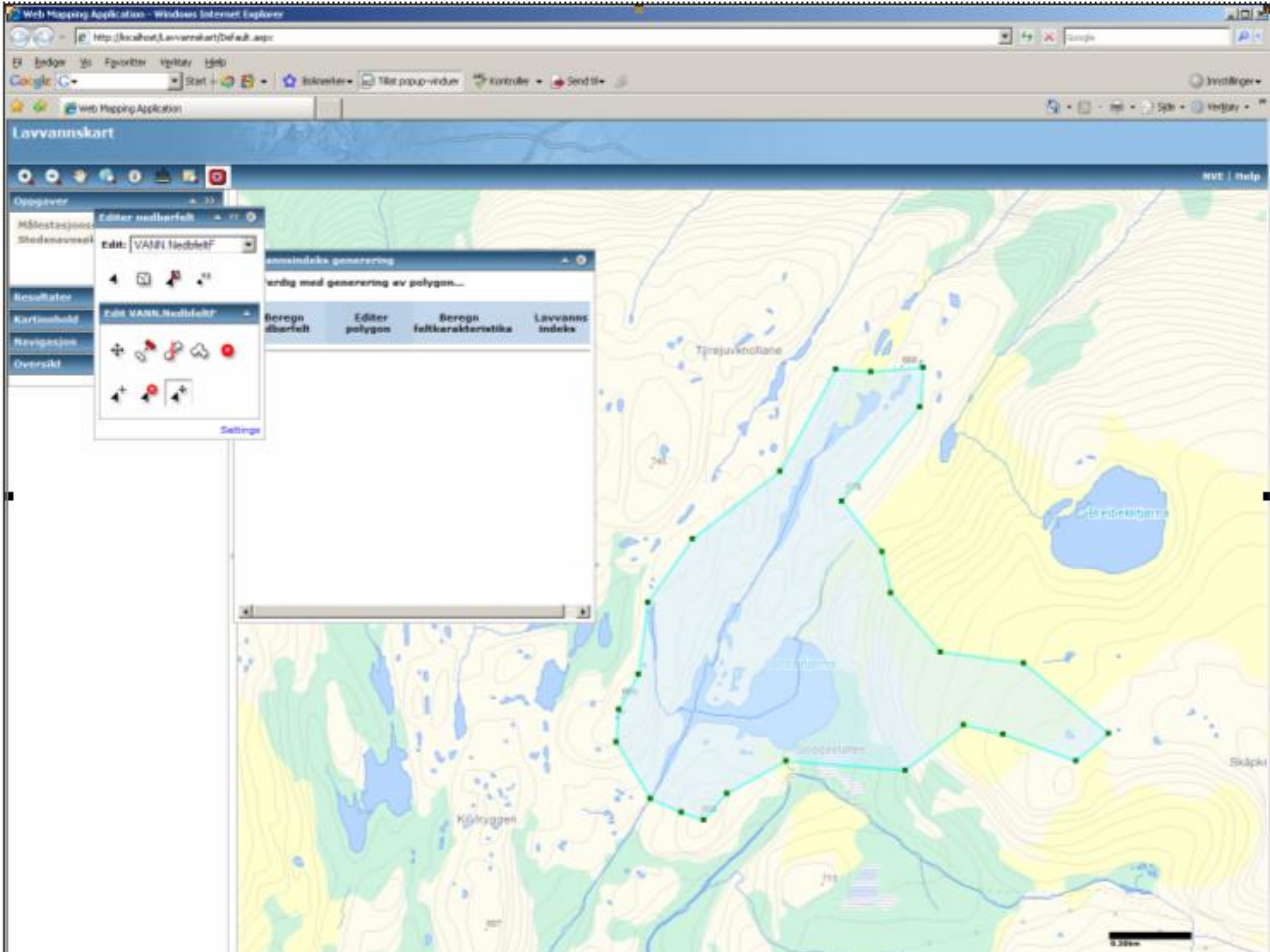
This takes time

- Goal is to have ‘ready to use’ grids and other required datasets covering Norway by the end of 2010

- The calculated low flow indices +- 20 % uncertainty
  - Must be used with caution

- Results have multipurpose range of use


Lavvannskart
Oppgaver
Målestasjonssøk
Stedsnavnsøk
Resultater
Kartinnhold
Navigasjon
Oversikt
Lavvannsindeks generering
Ferdig med generering av polygon...
Beregn nedbørfelt
Editer polygon
Beregn feltkarakteristika
Lavvanns indeks
Tirejuvknollane
Breibekktjørna
Kvilryggen
Soddastølen
745
713
697
0.20km


Web Mapping Application - Windows Internet Explorer
Web Mapping Application
Lavvannskart
NVE | Help
Oppgaver
Resultater
Kartinnhold
Navigasjon
Oversikt
Editer nedbørfelt
Edit: VANN NedbfeltF
Edit VANN.NedbfeltF
Settings
Ferdig med generering av polygon...
Beregn nedbørfelt
Editer polygon
Beregn feltkarakteristika
Lavvanns indeks

Identify

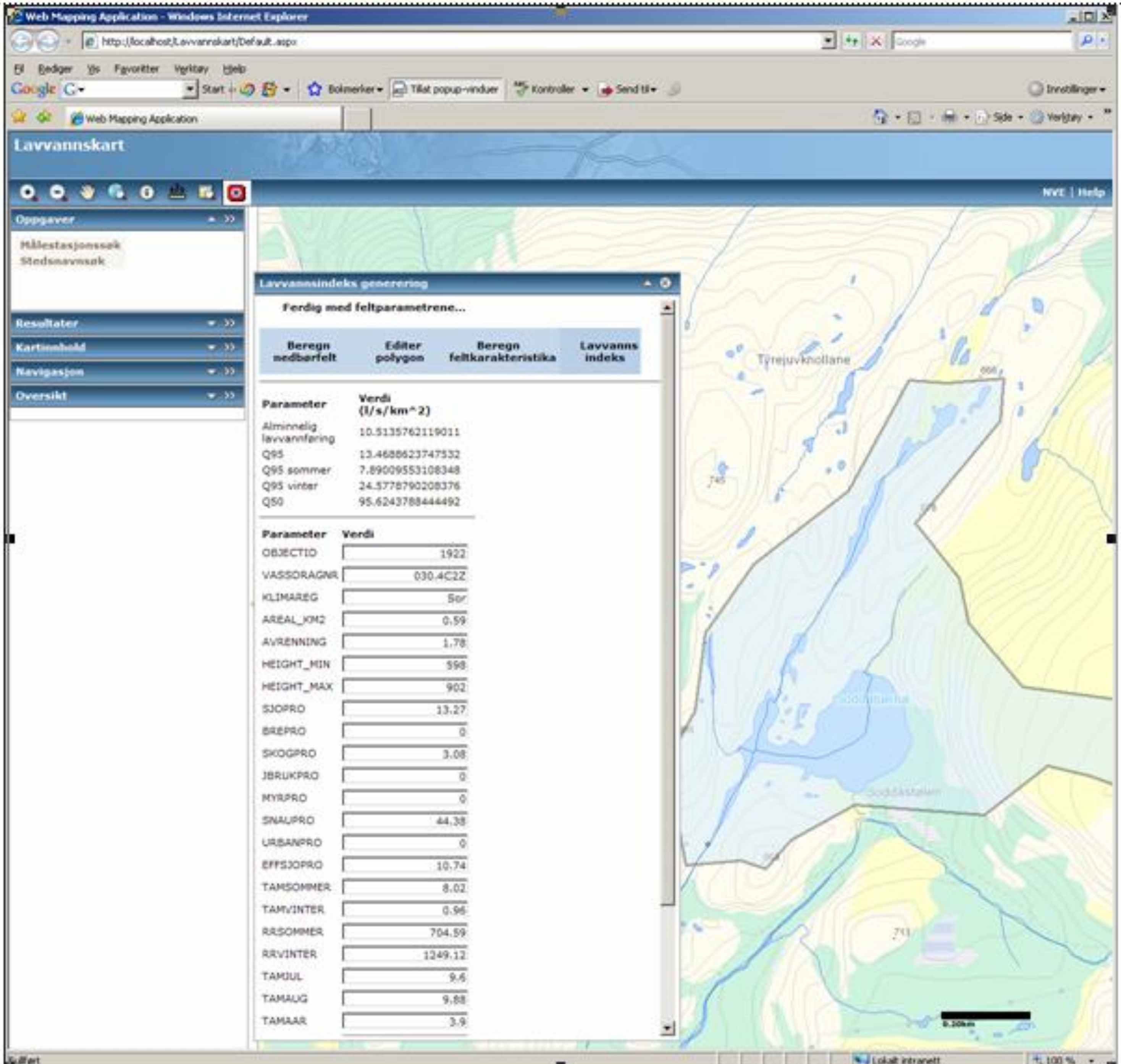
Identify from: VANN.NedbfeltF selection

VANN.NedbfeltF selection
030.4C2Z

Location: 3 301.412 6 571 240.423 Meters

Field	Value
OBJECTID	1923
ID	0
VASSDRAGNR	030.4C2Z
KLIMAREG	Sor
AREAL_KM2	0.58
AVRENNING	1.76
HEIGHT_MIN	603
HEIGHT_10	603
HEIGHT_20	612
HEIGHT_30	626
HEIGHT_40	636
HEIGHT_50	645
HEIGHT_60	659
HEIGHT_70	671
HEIGHT_80	711
HEIGHT_90	827
HEIGHT_MAX	902
SJOPRO	13.48
BREPRO	0
SKOGPRO	3.13
JBRUKPRO	0
MYRPRO	0
SNAUPRO	43.66
URBANPRO	0
EFFSJOPRO	11.04
TAMSOMMER	8.01
TAMVINTER	0.96
RRSOMMER	704.52
RRVINTER	1249.15
TAMJUL	9.59
TAMAUG	9.88
TAMAAR	3.9
RRAAR	1953.67
LENFELTKM	1.26
LENGDELVKM	1.04
GRADELV	28.61
GRAD1085	41.2
DELTAHMAX	29.63
FELTBREDDE	0.46
NUMID	0
GUID	67221a98d9adee957eb623f588ca4de8
AREA	0
LEN	0
Shape	Polygon
SHAPE.AREA	580546.60035
SHAPE.LEN	4092.516786

Identified 1 feature



Web Mapping Application - Windows Internet Explorer
http://localhost/Lavvannskart/Default.aspx
Web Mapping Application
Lavvannskart
NVE | Help
Oppgaver
Målestasjonssøk
Stedsnavnsøk
Resultater
Kartinnhold
Navigasjon
Oversikt
Lavvannsindeks generering
Ferdig med feltparametrene...
Beregn nedbørfelt
Editer polygon
Beregn feltkarakteristika
Lavvanns indeks
Parameter
Verdi (l/s/km^2)
Alminnelig lavvannføring
10.5135762119011
Q95
13.4688623747532
Q95 sommer
7.89009553108348
Q95 vinter
24.5778790208376
Q50
95.6243788444492
Parameter
Verdi
OBJECTID
1922
VASSORAGNR
030.4C2Z
KLIMAREG
Sor
AREAL_KM2
0.59
AVRENNING
1.78
HEIGHT_MIN
598
HEIGHT_MAX
902
SJOPRO
13.27
BREPRO
0
SKOGPRO
3.08
JBRUKPRO
0
MYRPRO
0
SNAUPRO
44.38
URBANPRO
0
EFFSJOPRO
10.74
TAMSOMMER
8.02
TAMVINTER
0.96
RRSOMMER
704.59
RRVINTER
1249.12
TAMJUL
9.6
TAMAUG
9.88
TAMAAR
3.9
Tyrejuvknollane
Lokalt intranett
100 %

Calculate the potential for small hydro power plants

Aim

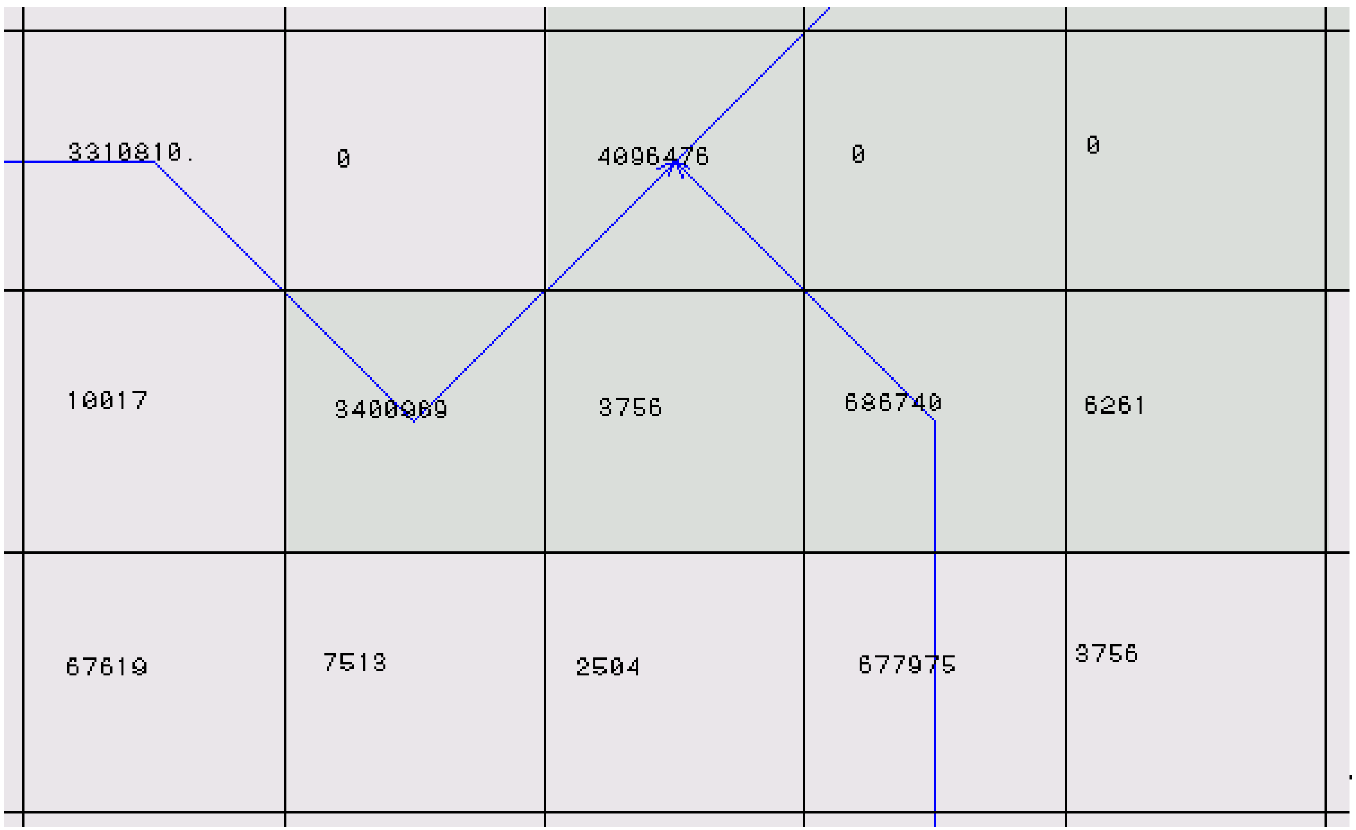
- Calculate small hydro plants energy potential
- Rough estimate
- Automatic using digital maps and GIS, manual correction
- RESULT: the theoretical potential for small hydro power plants .

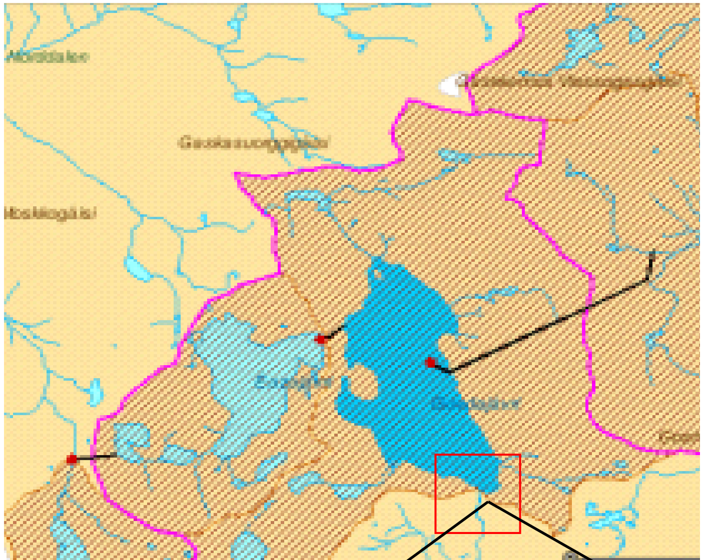
Steps in the Analysis

- Pre-processing hydrological grid
  - Flow accumulation grid model the regulated rivers
  - Weight flow accumulation grid using runoff grid as weight
- Generate river network as 3D rivers
- Calculate distance to roads and power lines
- The analyses

Derive runoff

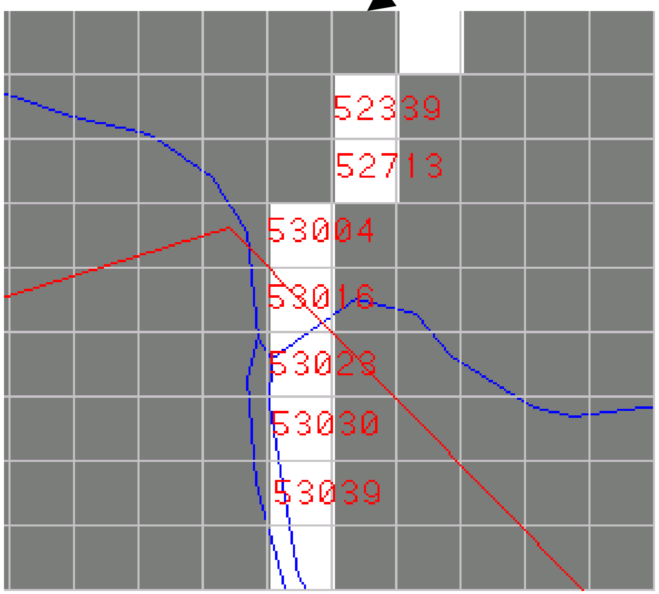
- **flow accumulation with runoff as a weight raster** - accumulated weight of all cells flowing into each down slope cell in the output raster.

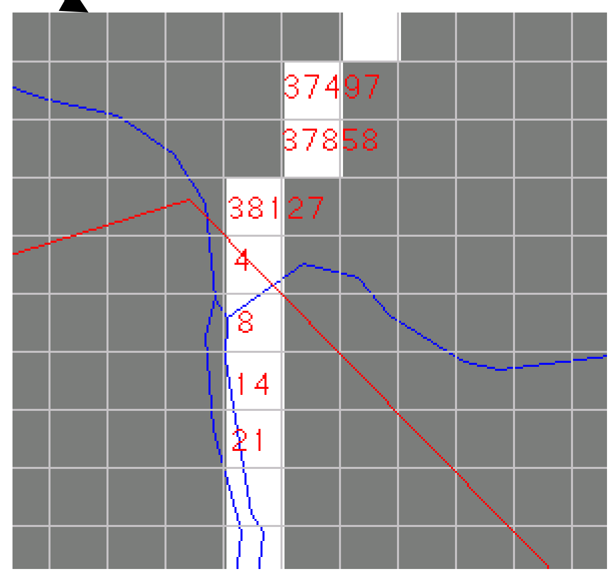




Change flowdir and flowacc for regulated rivers

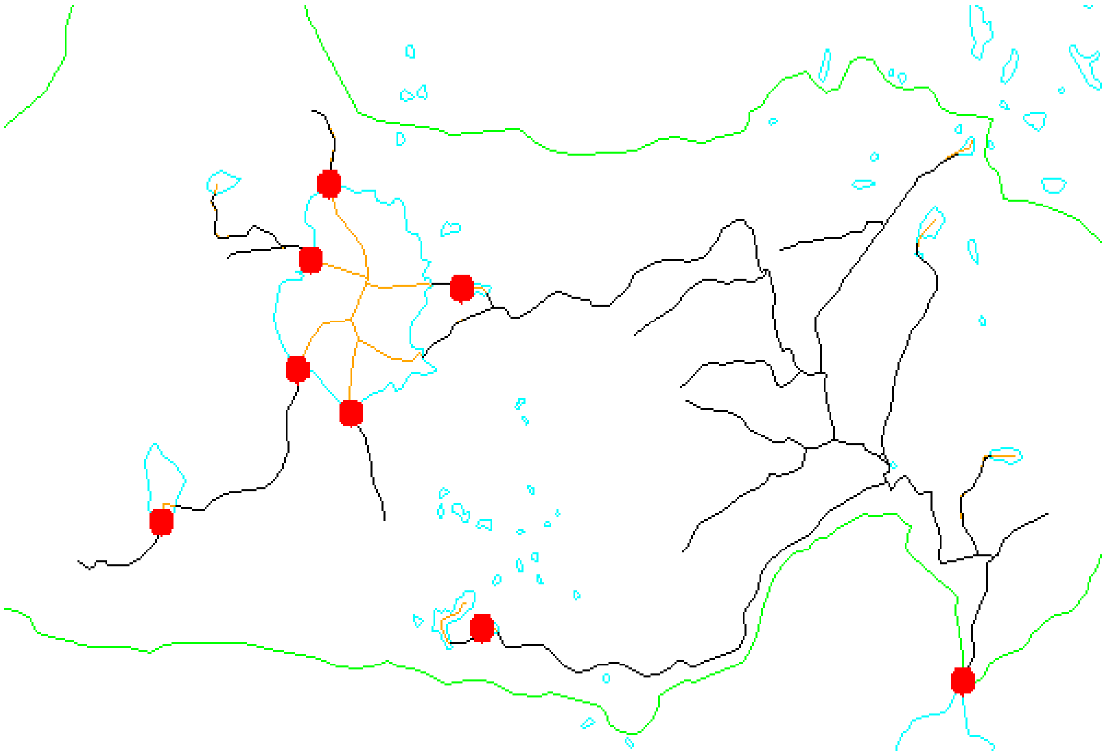
Use setmask when flowacc is generated





River network

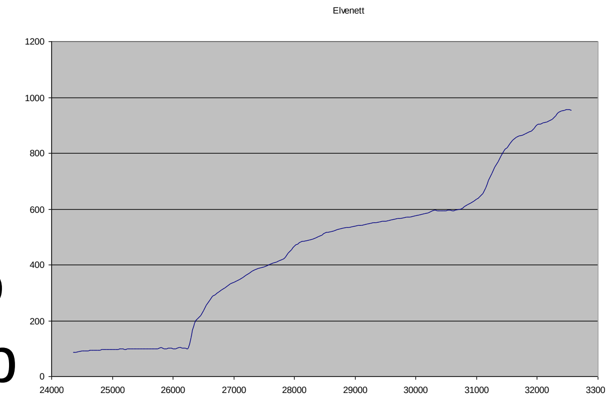
- Erase centreline in lakes and generate new outlet points



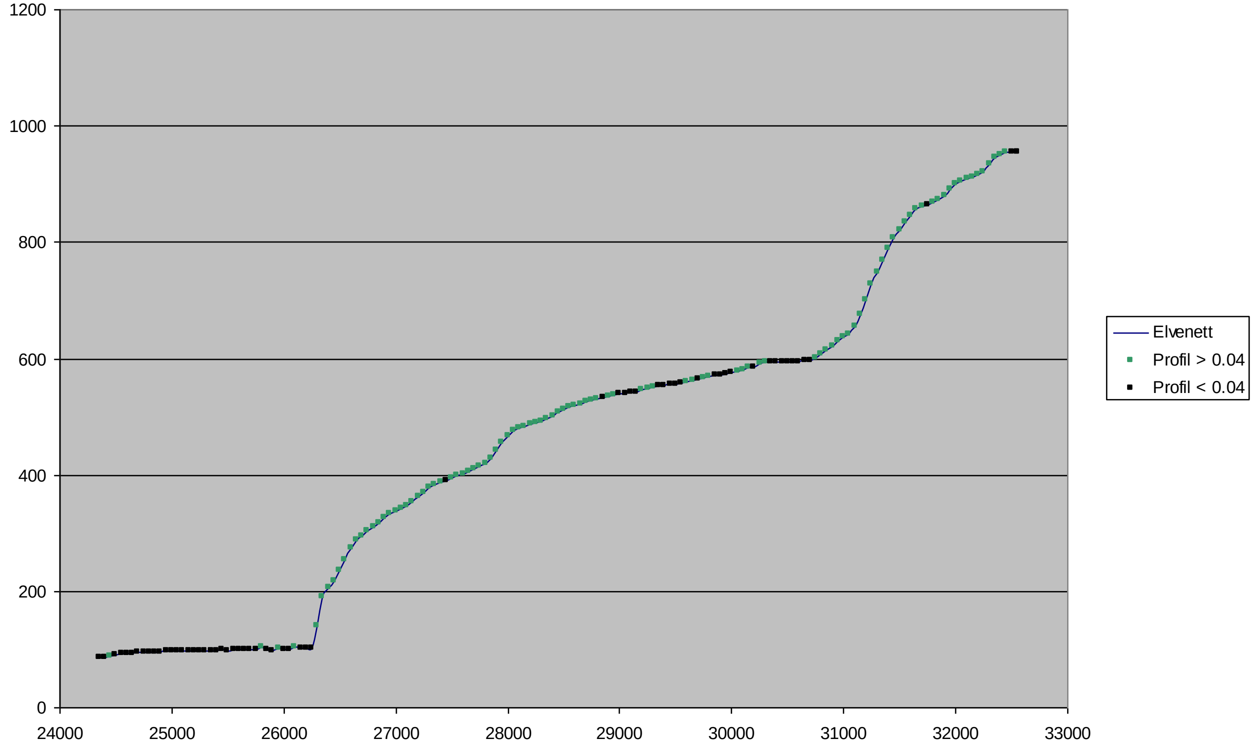
Steps in the analyse

- Identify slope
  - Calculate longitude profile
  - Identify downfall with gradient > 1:25
  - Find top and bottom of each slope
  - Calculate attribute to top of each slope
- Identify small hydro power plants which are within the conditions
- Calculate cost for each plant

Calculate profile



- Use ”utility network analysis” to trace all rivers from outlet to top
  - Each trace – longitude profile stored temporary
  - Dived profile in 50 meter sections – define point for each section (represent at top)
    - Attributes: difference of height, dH/dL.

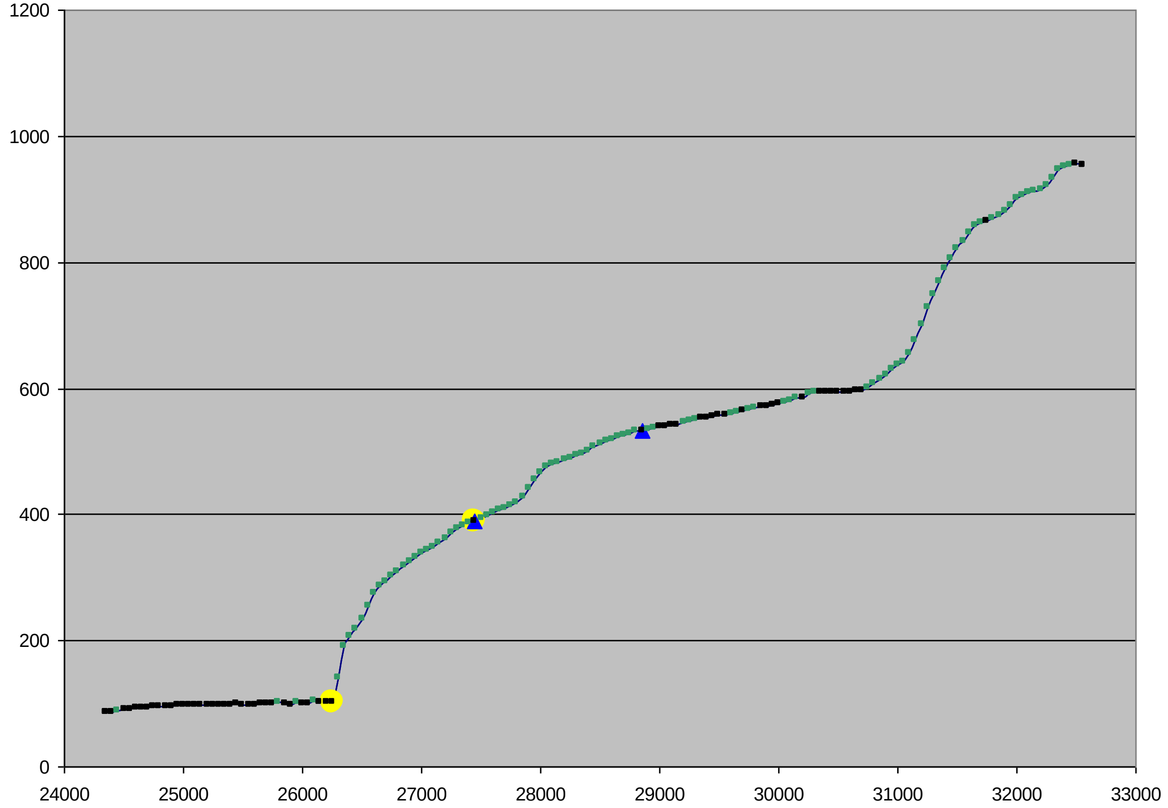


dH/dL for each 50 meter

< 0.04 - black vs. 1:25

> 0.04 - green

- Identify downfall
  - from outlet trace all profile points and start a slope where dH/dL > 0.04 and end where dH/dL gets < 0.04.



Blue triangle → intake
Yellow circle → power plant

Calculate parameters at intake

- Drainage area (flowacc)
- Runoff (flowacc weighted with runoff grid)
- Total difference of height

Conditions

- All rivers with downfall down to 1:25
- Relevant elevation limits (H) is 10 m - 600 m.
- Runoff 0.05 m^3/s – 25 m^3/s
- The turbine's maximum useable flow -
  (Q) = 1,5 x Q_{av} (average runoff).
- Installed power - N = 8,0 x Q x H
- Installed power limits - 50 kW-10000 kW.
- Production - 70 % of water can be used
- Production = 8,0 x (Volume pr year) x 0,7 x H x / 3600

Erase plants outside defined limitations

Cost accounting

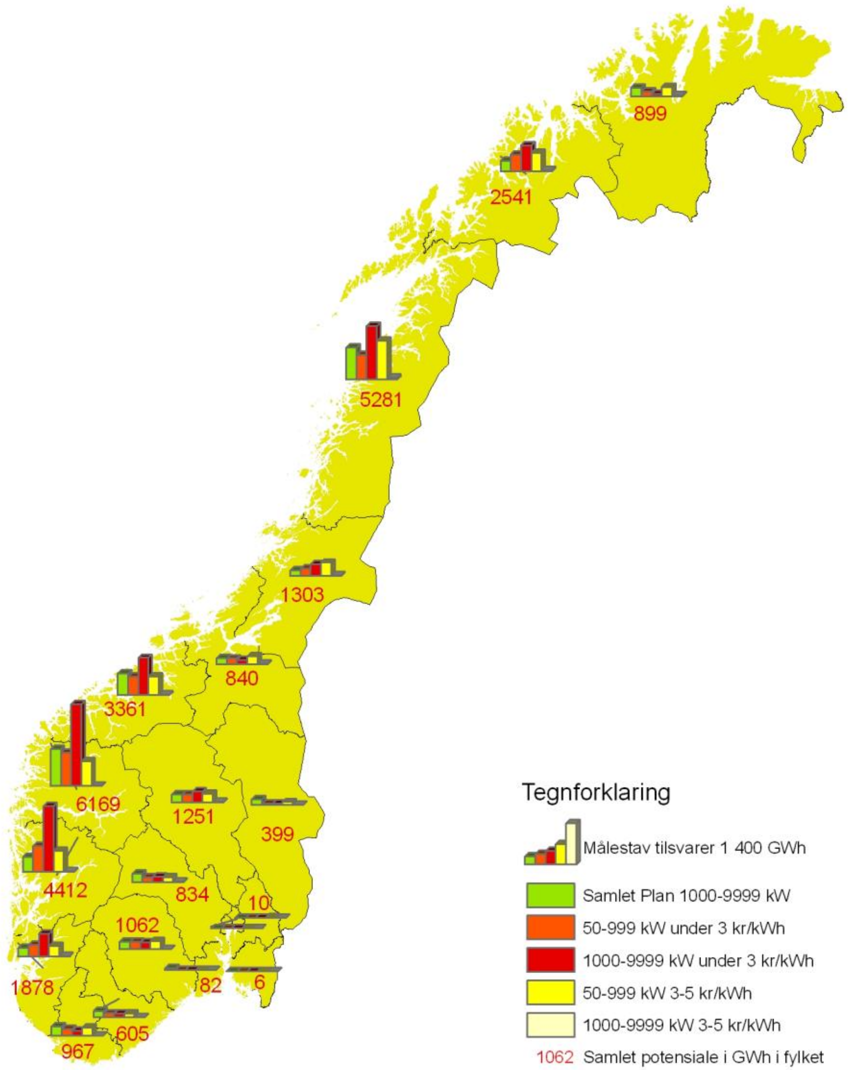
- Formula developed for small hydro plants
- Calculated based on
  - Elevation
  - Length of pipeline
  - Maximum useable flow
  - Distance to roads and transmission lines
  - Power

Results from the 2004 analysis

- Hydro power plans, intake and tunnels – information
  - Capacity- and cost
  - Catchment and municipality
  - Protected areas
  - Control status – build, planned, wrong
- Unique identification of power plants
  - 45529 total
  - 18637 < 5 NOK manually checked
  - 12871 outside restriction areas
  - 9467 accepted
    - 4128 < 3 NOK
    - 5339 3- 5 NOK

Potensialet for små kraftverk pr. 29.11.2004

Totalt: Samlet Plan: 7 TWh
GIS kartlegging under 3 kr/kWh: 18 TWh
GIS kartlegging mellom 3-5 kr/kWh: 7 TWh



Ressurskartlegging småkraftverk - Microsoft Internet Explorer provided by NVE
File Edit View Favorites Tools Help
Back Search Favorites Media
Address http://www.nve.no/modules/module_109/publisher_view_product.asp?iEntityId=7952 Go

Ressurskartlegging småkraftverk

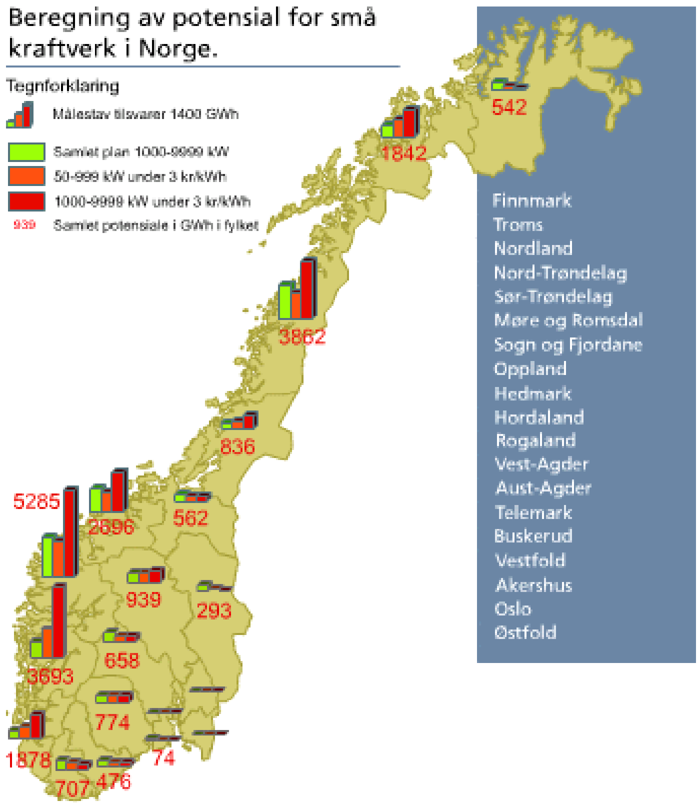
Skriv ut

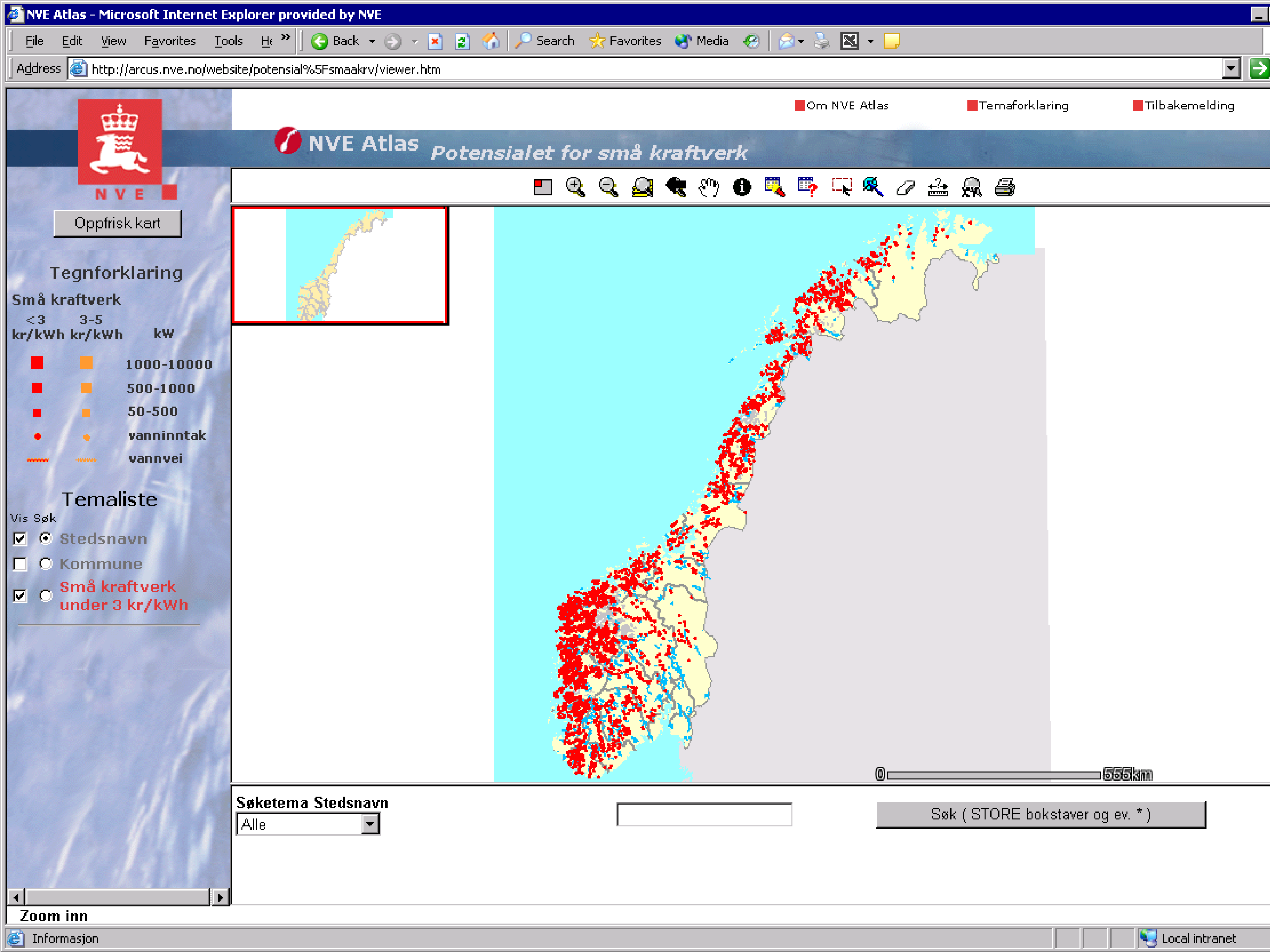
NVE har utviklet en ny metode for digital ressurskartlegging av små kraftverk mellom 50 og 10 000 kW. Metoden bygger på digitale kart, digitalt tilgjengelig hydrologisk materiale og digitale kostnader for de ulike anleggsdeler. Kartleggingen viser at det er realistisk å realisere ca 5 TWh av dette potensialet i løpet av en ti års periode.

Samlet er det funnet omkring 18 TWh med investeringskostnad under 3 kr/kWh. I tillegg kommer omtrent 7 TWh fra Samlet plan slik at potensial for små kraftverk under 10 MW med investeringsgrense 3 kr/kWh er rundt 25 TWh.

Ressursoversikten angir mulighetene for småkraftverk i hvert fylke i landet.

Kartleggingen er gjengitt i en rapport som også inneholder resultater og beskrivelse av metoden som er brukt med angivelse av svakheter på grunn av nødvendige forenklinger og det arbeid som må videreføres for å øke kunnskapen om ressursen ytterligere.




NVE Atlas - Microsoft Internet Explorer provided by NVE
File Edit View Favorites Tools He
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Address
http://arcus.nve.no/website/potensial%5Fsmaakrv/viewer.htm
Om NVE Atlas
Temaforklaring
Tilbakemelding
NVE
NVE Atlas
Potensialet for små kraftverk
Oppfrisk kart
Tegnforklaring
Små kraftverk
<3 kr/kWh
3-5 kr/kWh
kW
1000-10000
500-1000
50-500
vanninntak
vannvei
Temaliste
Vis Søk
Stedsnavn
Kommune
Små kraftverk under 3 kr/kWh
0
555km
Søketema Stedsnavn
Alle
Søk (STORE bokstaver og ev. *)
Zoom inn
Informasjon
Local intranet

NVE Atlas - Microsoft Internet Explorer provided by NVE

File Edit View Favorites Tools Help

Back Search Favorites Media

Address http://arcus.nve.no/website/potensial%5Fsmaakrv/viewer.htm Go

Om NVE Atlas Tegnforklaring Temaforklaring Tilbakemeld

NVE

Oppfrisk kart

NVE Atlas *Potensialet for små kraftverk*

Tegnforklaring

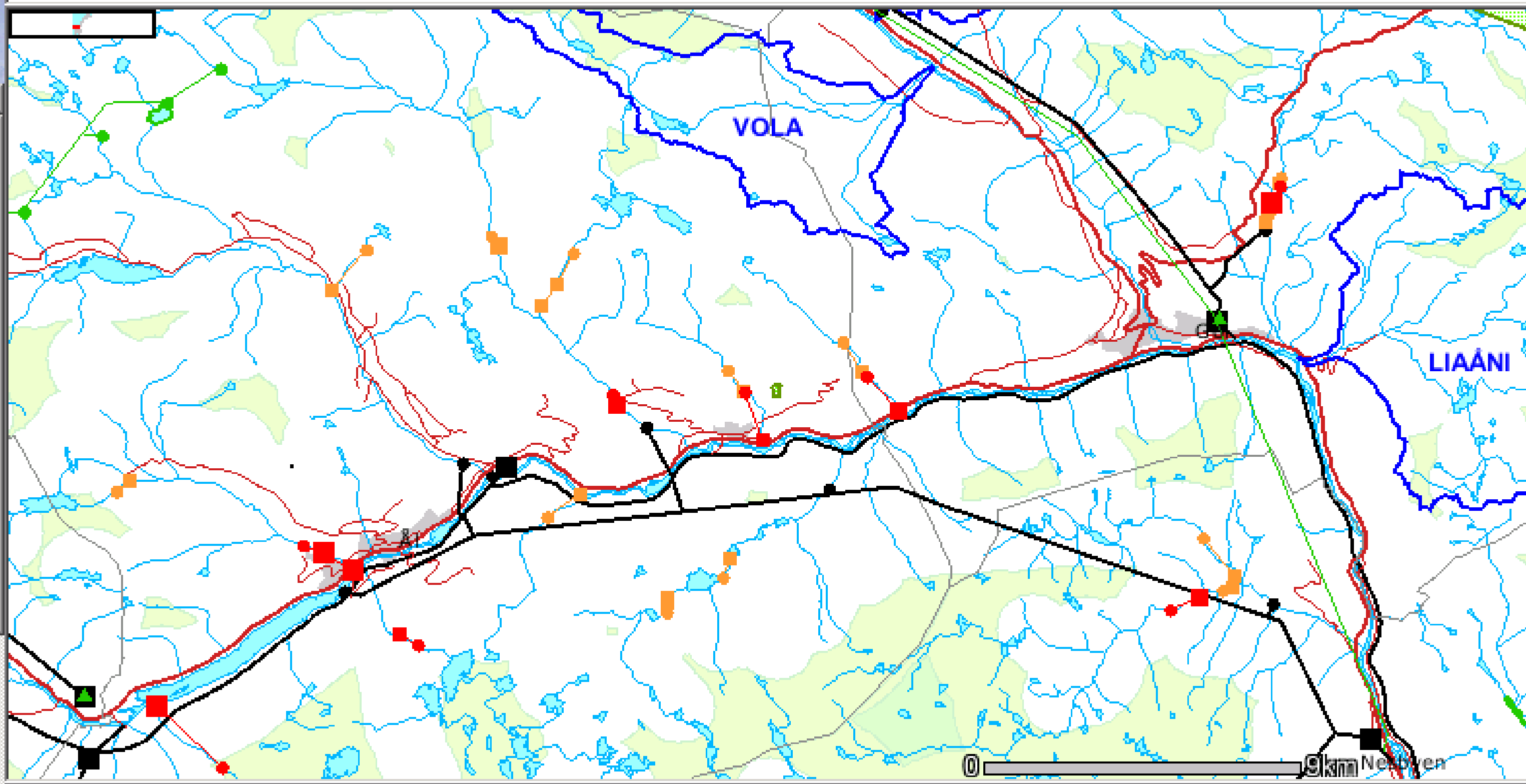
Små kraftverk

<3 kr/kWh	3-5 kr/kWh	kW
■	■	1000-10000
■	■	500-1000
■	■	50-500
•	•	vanninntak
----	----	vannvei

Temaliste

Vis Søk

- [x] Stedsnavn
- [ ] Kommune
- [ ] Innsjødata
- [x] Små kraftverk under 3 kr/kWh
- [x] Små kraftverk med 3-5 kr/kWh
- [x] Kraftverk i Samlet plan
- [x] - utvidelse
- [x] - magasin



Små kraftverk under 3 kr/kWh

Rec	KRVID	NEDBFELT	VANNFORING	DL	DH	HSTART	HSLUTT	EFFEKT	PRODUKSJON	TOTALKOST	PRISPRKWH	KOMMNR	KOMMUNE	VASSDRAGN
1	012.z_494	11,96	0,2	1400	329	282	610	770	3,15	7292	2,31	0617	Gol	012.CE1

Informasjon

Map: 180956.19 , 6739924.17 -- Image: 802 , 254 -- ScaleFactor: 54.97541026285382 Local intranet

New analyse from 2007
Improved datasets

- Improved flow direction and flow accumulation grid
  - Low flow index map project
  - Include runoff from Sweden and Finland
- New cost functions
- Erase transmission lines with high voltage from dataset
- Distance to roads calculated as shortest distance from power plant to the nearest road when lakes and steep areas area excluded. (In 2004 straight lines where used)

New method

- Identify location of intake and power plant depending of maximum effect
  - In 2004 – if discharge at top of head where too small, no power plant identified
  - In 2008 – program loop to find the optimal location
- Developed a … e user can located one plant an… are calculated for the power plant

Preliminary results

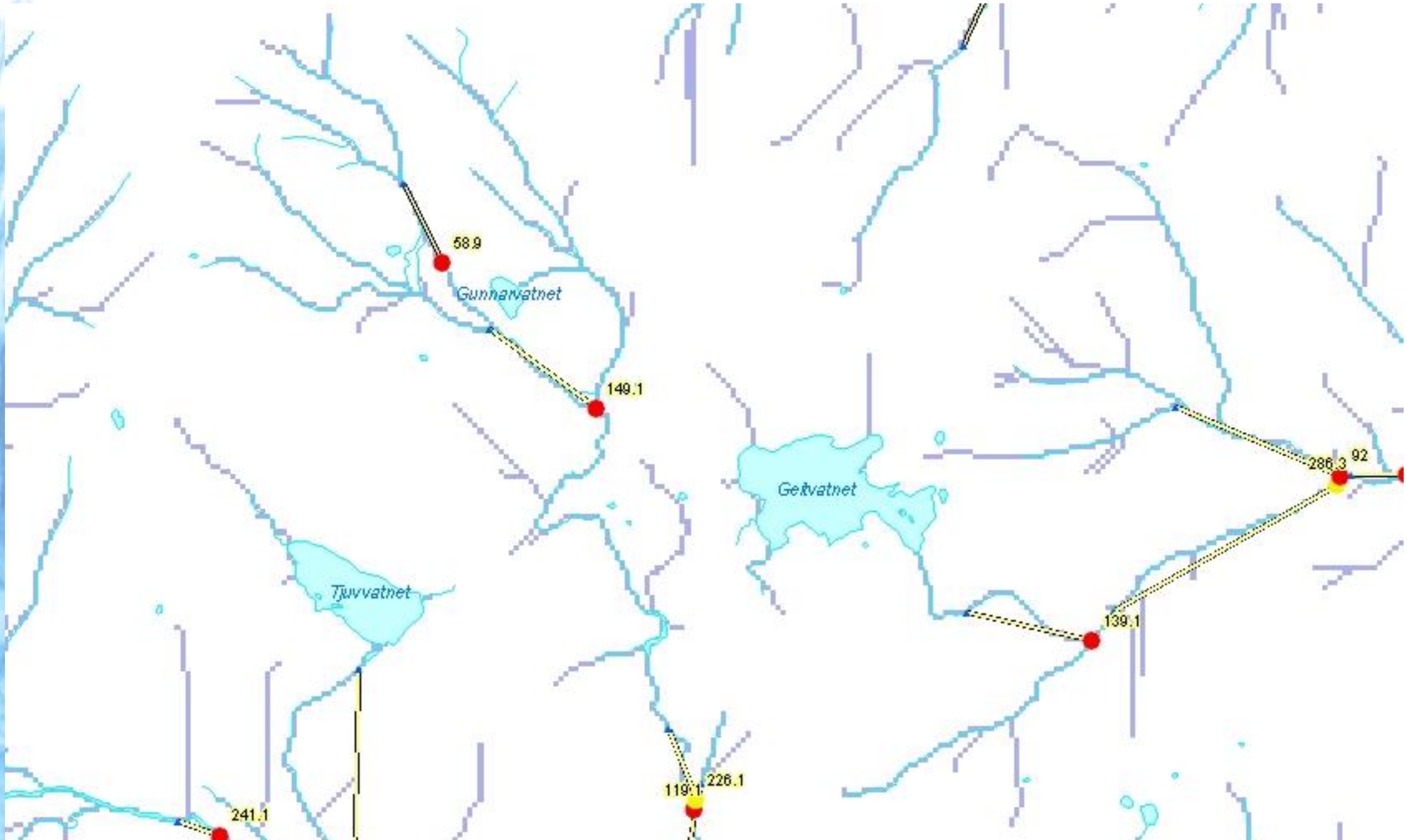
- 4 basins run with the new method
- Used distance to road as straight line
- Type of slope influence the cost and often the total cost has increased for steep slopes.
- More power plants have been identified due to search for optimal effect, but in some places too many plants in a row


92.5
79.9
123.2
70.5
287.1
75.2
87.6
84.5
70.3
Steinsvatnet
Storamos
Holmavatnet
Romavatnet
Stora Vandavatnet
Litla Vandavatnet

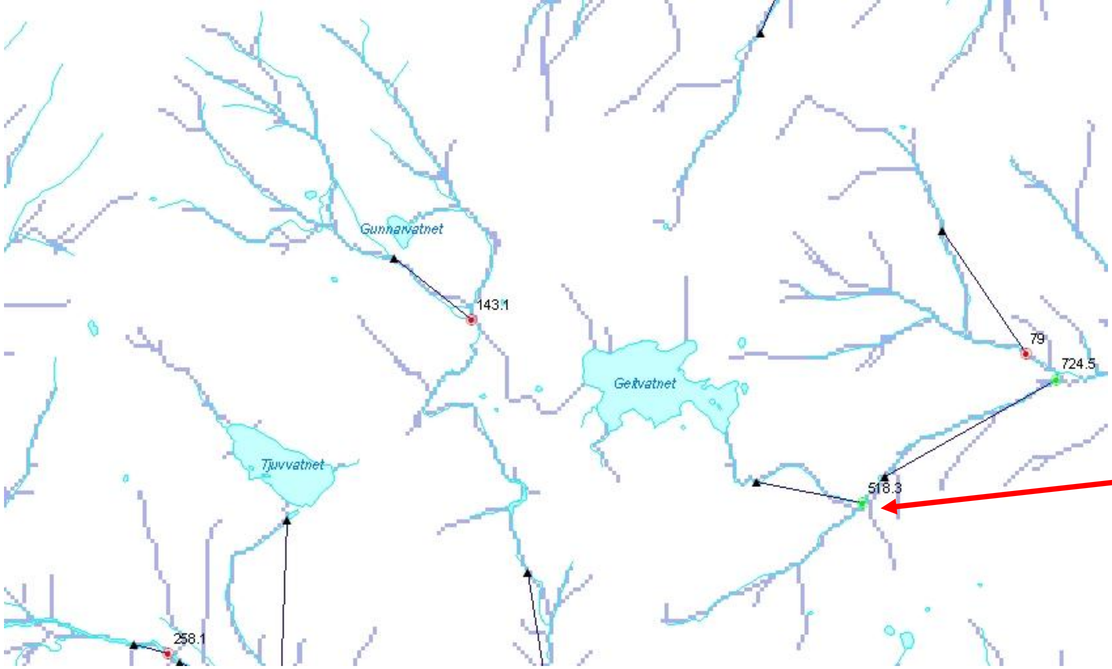
Preliminary results

- 4 basins run with the new method
- Used distance to road as straight line
- Type of slope influence the cost and often the total cost has increased for steep slopes.
- More power plants have been identified due to search for optimal effect, but in some places too many plants in a row
- More correct results – improved datasets

Result 2004   Result 2007

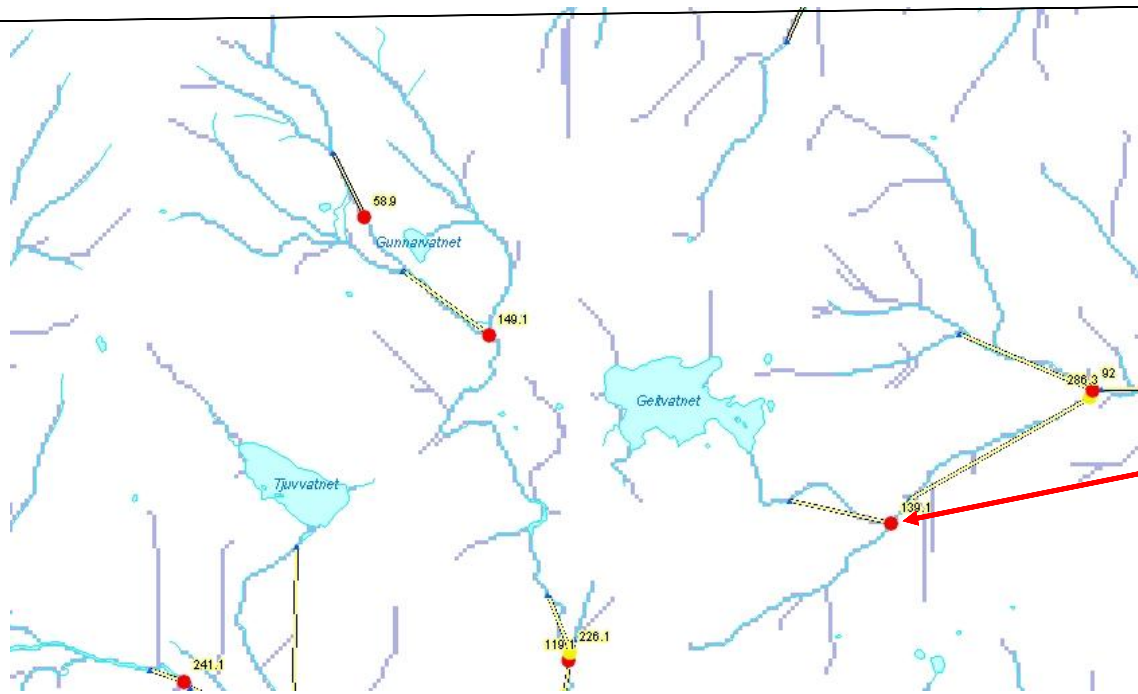


2004



518 kV

2007



139 kV

Preliminary results

- 4 basins run with the new method
- Used distance to road as straight line
- Type of slope influence the cost and often the total cost has increased for steep slopes.
- More power plants have been identified due to search for optimal effect, but in some places too many plants in a row
- More correct results
- Possible new national mapping, but first e few more basins will be run as a test

Calculate the potential for small hydro power plants