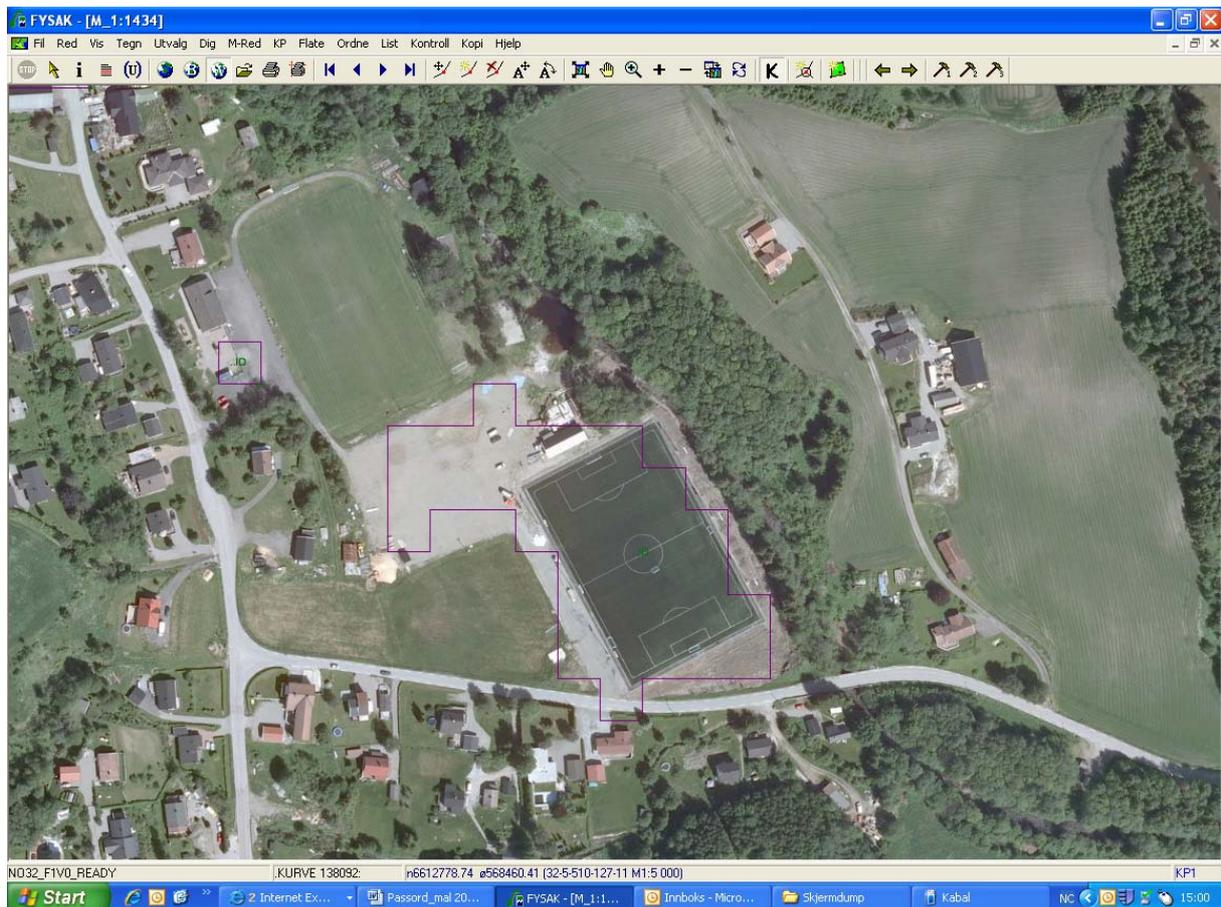


VERIFICATION OF HIGH RESOLUTION SOIL SEALING LAYER - QUALITATIVE ASSESSMENT -



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26 June 2008

INTRODUCTION

The “High resolution soil sealing layer” (HR-SS) was received from the European Environmental Agency (EEA) by ftp on 3 June 2008. The Norwegian Forest and Landscape Institute has carried out a qualitative assessment of the data following the guidelines provided in the “Guidelines for verification of high resolution soil sealing layer” v 1.0 published by EEA 3 December 2007.

The verification team consisted of

Ms. Hanne Gro Wallin	Team leader/Coordination
Ms. Britt Lindstad	GIS Engineer/Airphoto interpretation
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Ms. Marit Johannessen	GIS Engineer/Airphoto interpretation
Dr. Arnt-Kristian Gjertsen	Image analysis/Data preparation
Dr. Geir-Harald Strand	Supervision and reporting

The HR-SS image data were recoded with areas having ≥ 80 % soil sealing represented as “1” and the remaining areas represented as “0”. The areas represented as “1” were retrieved and polygonized and a new polygon map of areas having ≥ 80 % soil sealing (HR-SS-80) established. HR-SS-80 were then inspected in combination with two other datasets in order to assess the quality of the dataset.

The two additional datasets were

The national orthophoto database (a public, somewhat degraded version can be viewed at www.norgebilder.no)

National topographic maps (scale 1:50,000)

Some of the data in the two ancillary datasets did not originate in 2006, but is either older or younger than the HR-SS data. The interpreters have as far as possible accounted for these differences.

SUMMARY

The geometrical accuracy of the HR-SS datasets for Norway is excellent.

Both HR-SS and HR-SS-80 are good renditions of the geography of sealed areas in Norway when the results are presented on small scale maps (1:5 00 000) where details are discarded and focus is on the overall national distribution of sealed land.

HR-SS-80 is a *good* geographical representation of sealed land within “urban” (or densely built up) areas, including industrial sites.

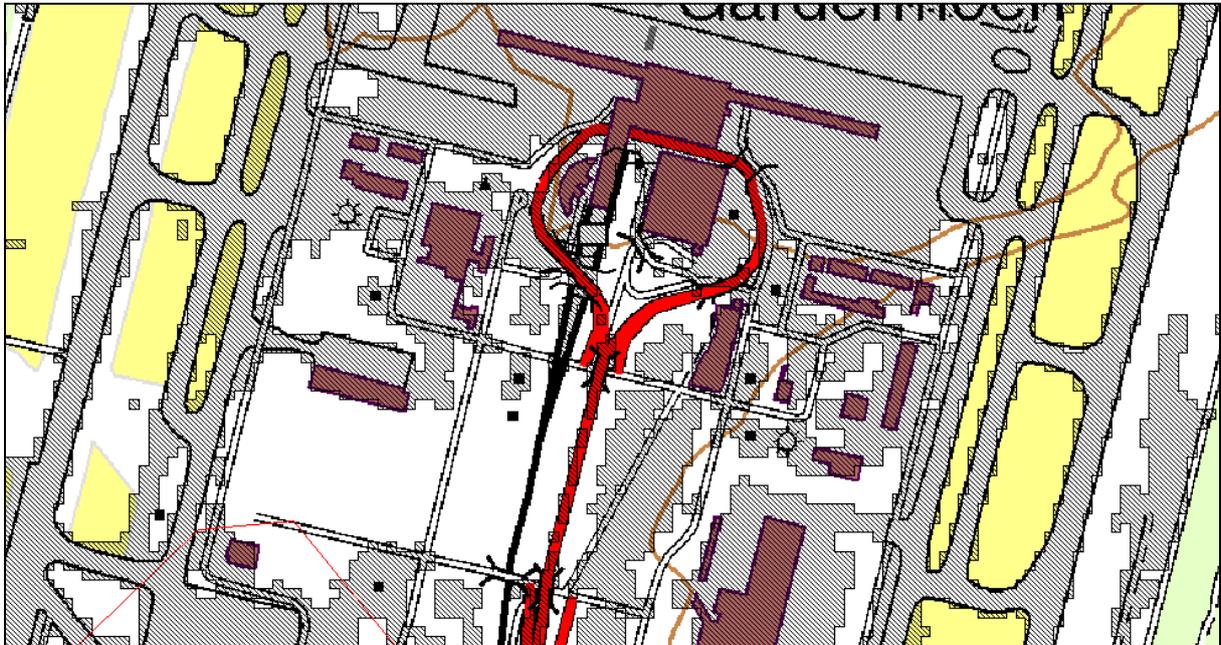
HR-SS-80 is an *insufficient* geographical representation of sealed land in “rural” areas and the outfields and lower mountains. Only a small fraction of these areas are sealed, but the inclusion of actually sealed areas in HR-SS-80 is coincidental. Furthermore, some of the areas included in HR-SS-80 are not permanently “sealed” but instead areas where the vegetation is temporary removed.

HR-SS-80 is of excellent quality for land cover types without any soil sealing, where the dataset correctly shows no soil sealing.

The statistical quality of HR-SS and HR-SS-80 is unknown. Sealed land in “rural” areas is obviously underrepresented in HR-SS-80, but this may be leveled out by the representation of percentage sealing in HR-SS. Norway has databases, including 1:5 000 digital maps, a fairly complete register of buildings and a complete road database that can provide for compilation of much more reliable and accurate statistics than HR-SS. We therefore recommend that even though the data may be used for statistical purposes on the European level, statistical results should not be published for Norway or parts of Norway based on these data.

GEOMETRY

The geometric quality of HR-SS for Norway is excellent. This is illustrated by the overlay between HR-SS-80 (gray area) and the topographic map for the Oslo airport Gardermoen. The sealed runways surrounded by grass are mapped with high accuracy and there is no visible shift in the map. See also example A.2.



Similar inspections, using both topographic maps and ortophoto, were carried out for all the six datasets in the HR-SS delivery. Particular attention was given to the fiords on the Norwegian west coast where geometric correction of images can be difficult due to the rapid variation in elevation. The geometric quality was always very good. The image below shows the Årdal industrial site where the delineation of the port is excellent.



A comment regarding UTM zone 31

Data were delivered as separate datasets for UTM zones 31 – 36. UTM zone 31 does, however, not exist in Norway. In the international definition of the UTM system, there are two exceptions from the regular zoning system. One of these exceptions is in Norway where zone 32 is extended westward to include the west coast of the country. Data for Norway should not be delivered as projected to UTM zone 31, but UTM zone 32 should be used for the whole western part of southern Norway.

Qualitative assessment

HR-SS for Norway was delivered as six datasets, one for each UTM zone 31 through 36. All six datasets were inspected. The quality of the results did not show any detectable variation between datasets. The assessment made for each land cover type is therefore valid for all six datasets.

There is considerable regional variation with respect to how well certain sealed land types are represented in HR-SS-80. This is in particular true for roads, transport network and for gravel covered surface on parking lots, industrial sites and soccer fields. We suspected that these differences were related to and could be explained by the different satellite sensors used in the image mosaic. A simple, qualitative assessment did, however, *not* support this theory. The regional differences are therefore still not explained.

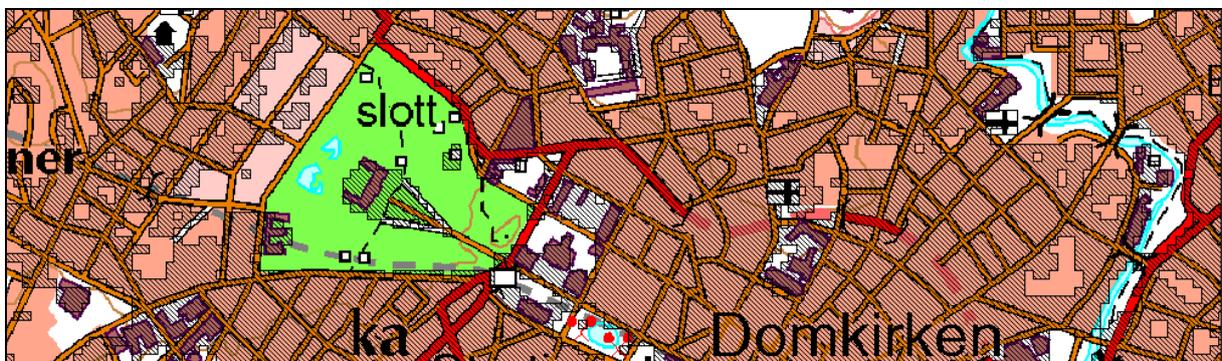
The assessment methodology has emphasized sealed land. Within each of the broad land cover type, the assessment is based on two questions:

- Is the sealed land correctly mapped as “sealed”?
- Is the land that is mapped as “sealed” really sealed?

The third possible question: Is unsealed land correctly mapped as “not sealed”? is not part of the assessment. The assessment for a land cover type without sealed land (eg glaciers) will therefore be “excellent” as long as no areas incorrectly have been mapped as “sealed”. The assessment for a land cover type with a few, small pockets of sealed land can, on the other hand, be “very poor” if these small pockets are incorrectly mapped as “not sealed”.

Urban fabric

HR-SS-80 for densely built up, urban areas is *good*. Parks and other green spots, including backyards with trees are not marked as “sealed”. This is illustrated by the map of central Oslo where the sealed area ends abruptly along the park surrounding the royal castle. Other central parks are also “not sealed”. The data are also probably good, but the accuracy more uncertain in areas where the urban fabric is more green (as in the leftmost part of the map below).

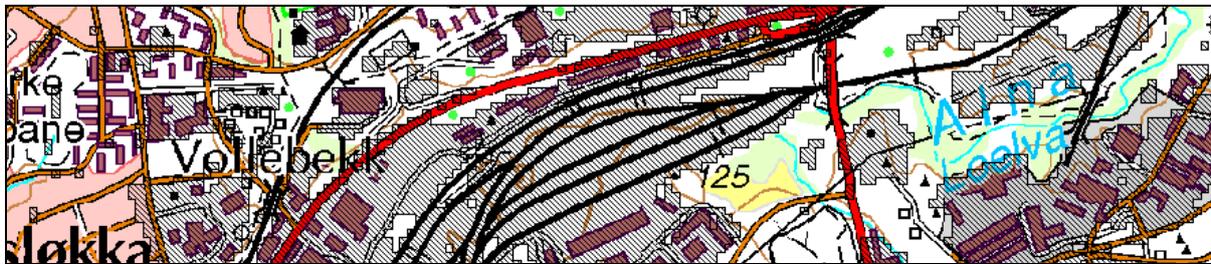


Industrial or commercial units

HR-SS-80 for industrial and commercial units is *good*. Much of the area is *excellent*, in particular regarding large industrial or commercial sites. Smaller factories or shops are some times noticeable exceptions. The exceptions include areas where the ground surrounding the buildings is unpaved.

Road and rail networks and associated land

HR-SS-80 for the road and rail network is *acceptable* in areas where it is closely linked to urban fabric or industrial or commercial units, but *very poor* outside such areas. The map below shows how the railway is “sealed” in the major Oslo cargo terminal but not outside it (where the railway continues on the right hand side of the map). The road network is inconsistently represented, even in this densely built up area. In rural areas, the road network only appears occasionally at intersections or in areas without roadside vegetation. A highway passing through a forest may not be visible in the map while a similar road in mountain areas with little or no roadside vegetation is clearly mapped.



Port areas

HR-SS-80 is generally of *good* quality in port areas. The delineation of the waterfront is usually *excellent*, but areas within the port is sometimes marked as “not sealed” if the surface has not been paved. Some of these areas should be considered as “sealed” although the surface material may be gravel.

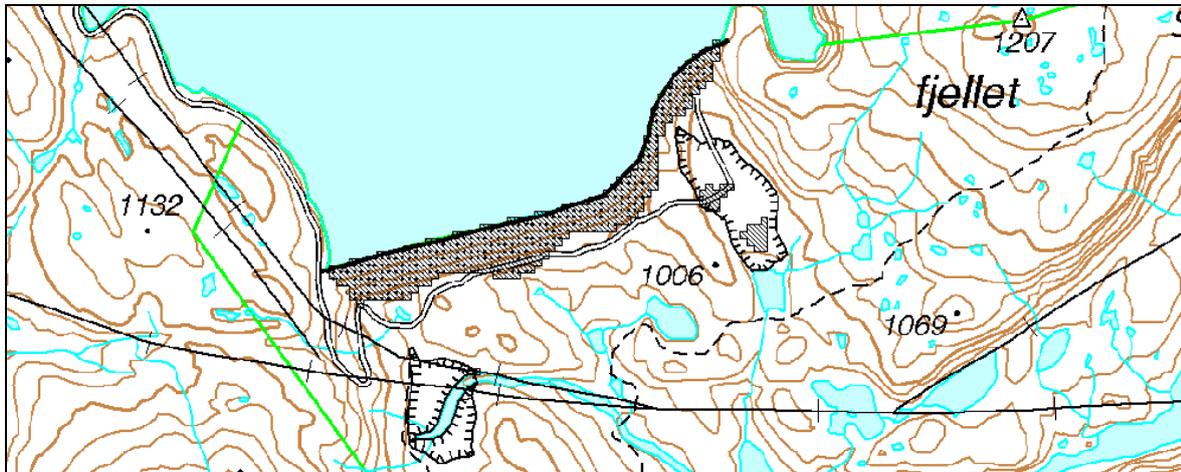
Airports

HR-SS-80 is of *excellent* quality for airports with paved runways but of *very poor* quality for smaller airports (airstrips) with runways covered with gravel



Mine, dump and construction sites

HR-SS-80 is of *very good* quality for open pit mines and dumps linked to mines but inconsistent and insufficient for quarries and gravel pits. Dump sites, as the hydropower dam shown in the map below,



are represented well. Notice, however, how the two extraction sites (quarries) near the dam is “not sealed”. (From Blåsjø, Bykle).

Small and medium sized gravel and sand pits are common in Norwegian rural areas and outfields. These pits are usually, but not always, remains from local road construction. Some of these pits are mapped as “sealed”, some not, and there is no obvious explanation of the differences. These inconsistencies appear on arable land, in agricultural areas; forest and scrubland. The problem is mentioned here, instead of describing it under each one of these land types. The partial coverage of one of the two quarries in the map below illustrates the problem which also is documented in the annexes.

Arable land

HR-SS-80 does correctly classify arable land (here understood as homogeneous agricultural land) as “not sealed”. Farmyards are, however, also (in most cases) classified as “not sealed”. Many farmyards, especially on arable land but also in more heterogeneous agricultural areas, contain many buildings, including large barns. Still, these locations are usually not marked as “sealed”. One of Norway's largest barns is found on the farmyard circled in the map below. The location is, according to HR-SS-80, not sealed. Roads and railways through these landscapes are usually not mapped as sealed.



Heterogeneous agricultural land

HR-SS-80 does correctly classify heterogeneous agricultural land as “not sealed”. The comments regarding farmyards, roads and gravel pits above, does, however, also apply to these areas.

Forest

HR-SS-80 does correctly classify forest as “not sealed”. The comments regarding roads and gravel pits above, does also apply to these areas.

Scrub and/or herbaceous vegetation associations

HR-SS-80 does correctly classify scrubs as “not sealed”. The comments regarding roads and gravel pits above, does also apply to these areas.

Beaches, dunes and sand

Beaches, dunes and sand are not common in Norway. We have inspected known beaches and they are correctly represented as “not sealed” in HR-SS-80. Norway’s only known desert – Kvitsanden, Røros – is also correctly represented as “not sealed” (see map below). Sand extraction sites on the fringe of Kvitsanden are, however, mapped as sealed.



Bare rocks

HR-SS-80 does correctly classify bare rocks as “not sealed”.

Sparsely vegetated areas

HR-SS-80 does correctly classify sparsely vegetated areas as “not sealed”. The comments regarding roads and gravel pits above, does also apply to these areas.

Glaciers and perpetual snow

HR-SS-80 does correctly classify glaciers and perpetual snow as “not sealed”.

Inland wetlands

HR-SS-80 does correctly classify inland wetlands as “not sealed”. The comments above regarding roads, does also apply to these areas.

Peatland

HR-SS-80 does correctly classify peatland as “not sealed”. The comments above regarding roads, does also apply to these areas.

Peatland is not mentioned in the Guidelines for assessment, but is an important land cover type in Norway.

Salines

Salines were not assessed. .

Intertidal flats

HR-SS-80 does correctly classify intertidal flats as “not sealed”. The comments above regarding roads, does also apply to these areas.

Coastal lagoons

Coastal lagoons were not assessed.

Conclusion

HR-SS-80 is a *good* geographical representation of sealed land within “urban” (or densely built up) areas, including industrial sites.

HR-SS-80 is of excellent quality for land cover types without any soil sealing, where the dataset correctly shows no soil sealing.

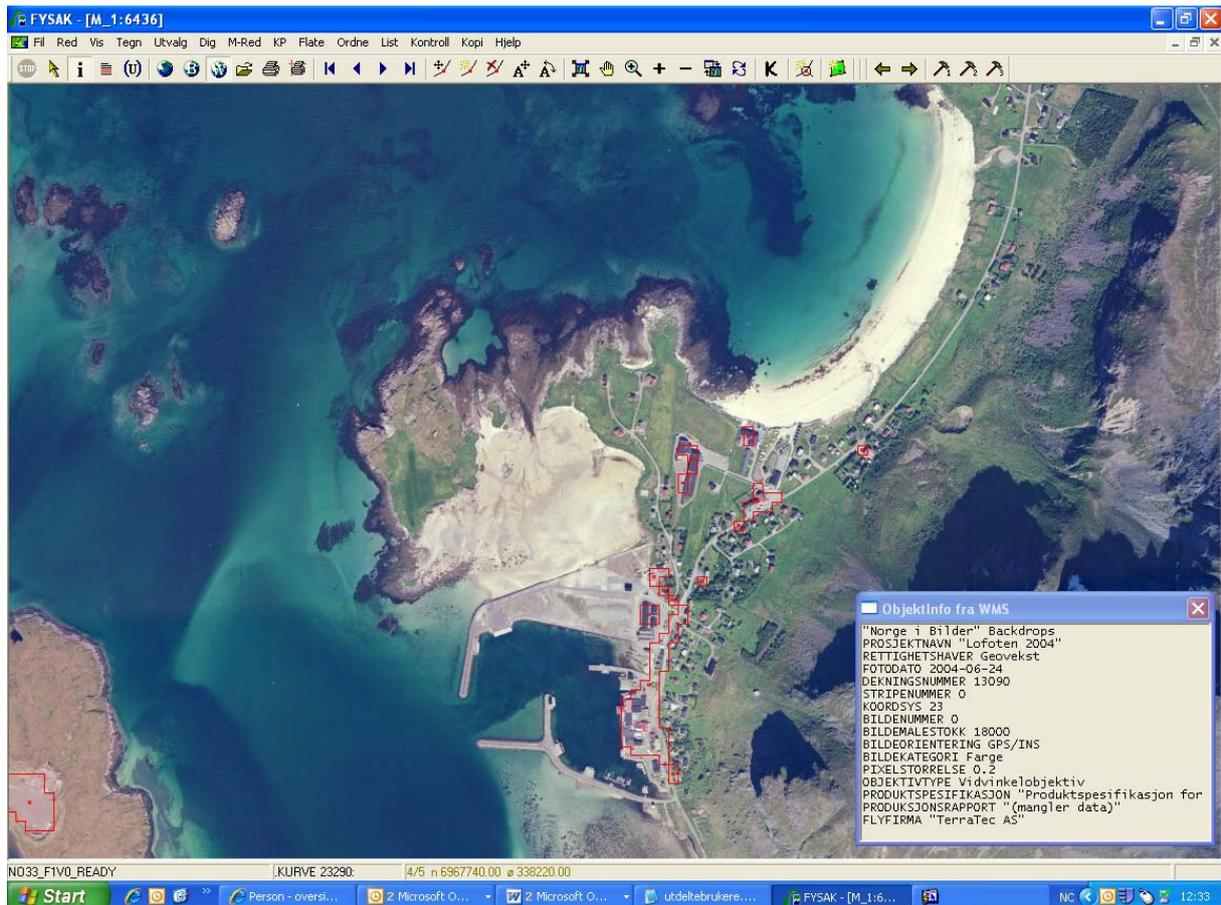
HR-SS-80 does correctly classify most of the rural and outfield areas where sealed land is scattered, infrequent and uncommon as “not sealed”. HR-SS-80 is, however, a poor geographical representation of those locations that are sealed in the rural areas and in the outfields and mountains. Only a very small fraction of these areas are sealed, but the inclusion of actually sealed areas in HR-SS-80 is coincidental. Furthermore, many of the areas included in HR-SS-80 are not permanently “sealed” but instead areas where the vegetation is temporary removed. For these land cover types, our assessment is that the result is *insufficient*. This is an assessment emphasising the quality of the mapping of the sealed location, not of the overall land cover type. If we assess the overall land cover types the assessment would be very good or excellent because most of the land correctly is mapped as “not sealed”.

The representation of areas sealed as roads and related land is inconsistent and poor in HR-SS-80. So are areas used for gravel and sand pits.

Annex A: Ortophoto examples

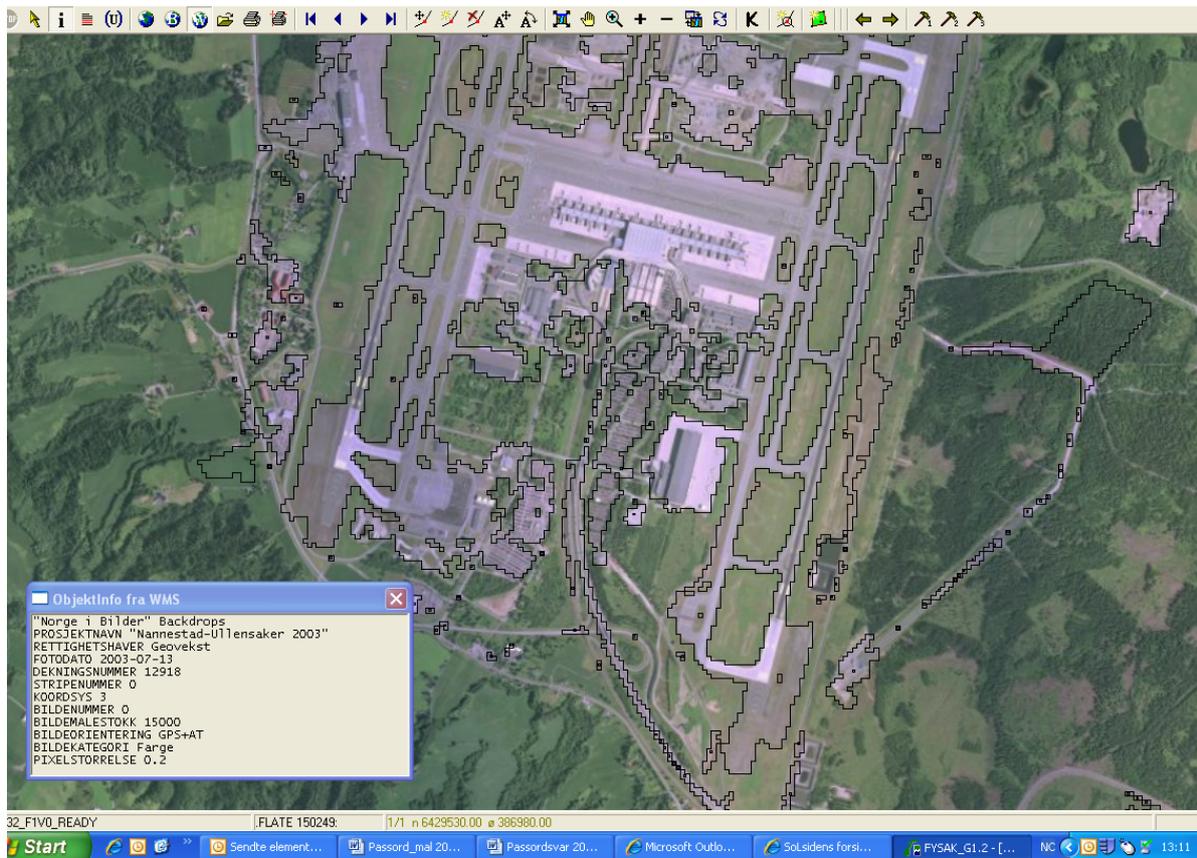
These selected cases exemplify some of the comments linked to the qualitative assessments above. The screen dumps shows HR-SS-80 on top of ortophoto. Sealed areas according to HR-SS-80 are shown as red squares. Some of the screen dumps have a superimposed white grid representing the pixels in HR-SS for reference.

Example A.1: Beach and port in Flakstad [UTM-33: 426 200, 7 553 750]



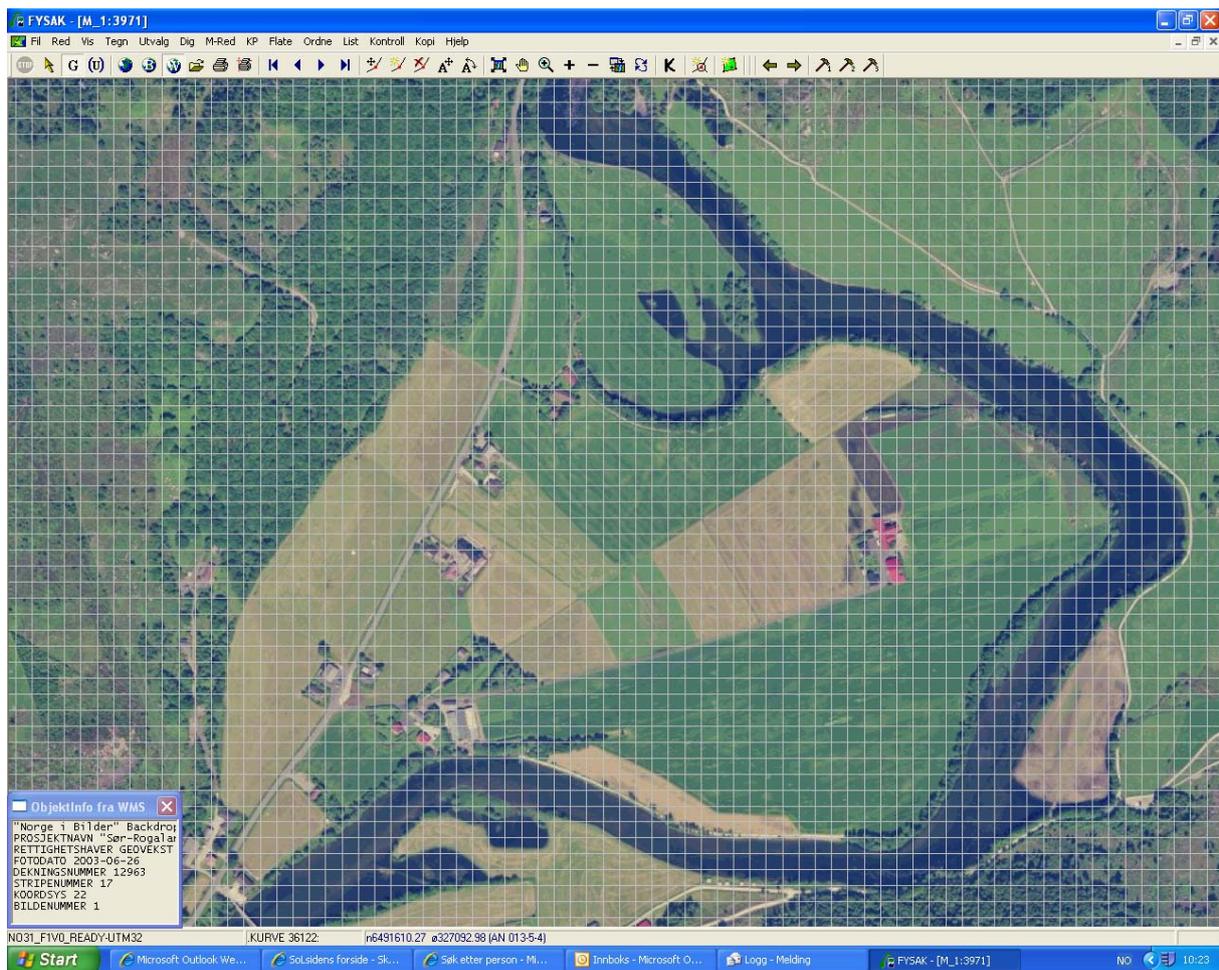
The example shows how beaches and sand dunes are correctly represented as “not sealed”. A considerable part of the port that is covered with rocks and sand is also “not sealed”. This area is an “artificial tidal flat” filled with water during high tide and exposed during outgoing tide. The built up part of the port area is correctly mapped as “sealed”. Furthermore, notice the “sealed” spot on Torvø island in the lower left corner. This site is a quarry.

Example A.2: Oslo Airport Gardermoen [UTM-32: 616 200, 6 674 700]



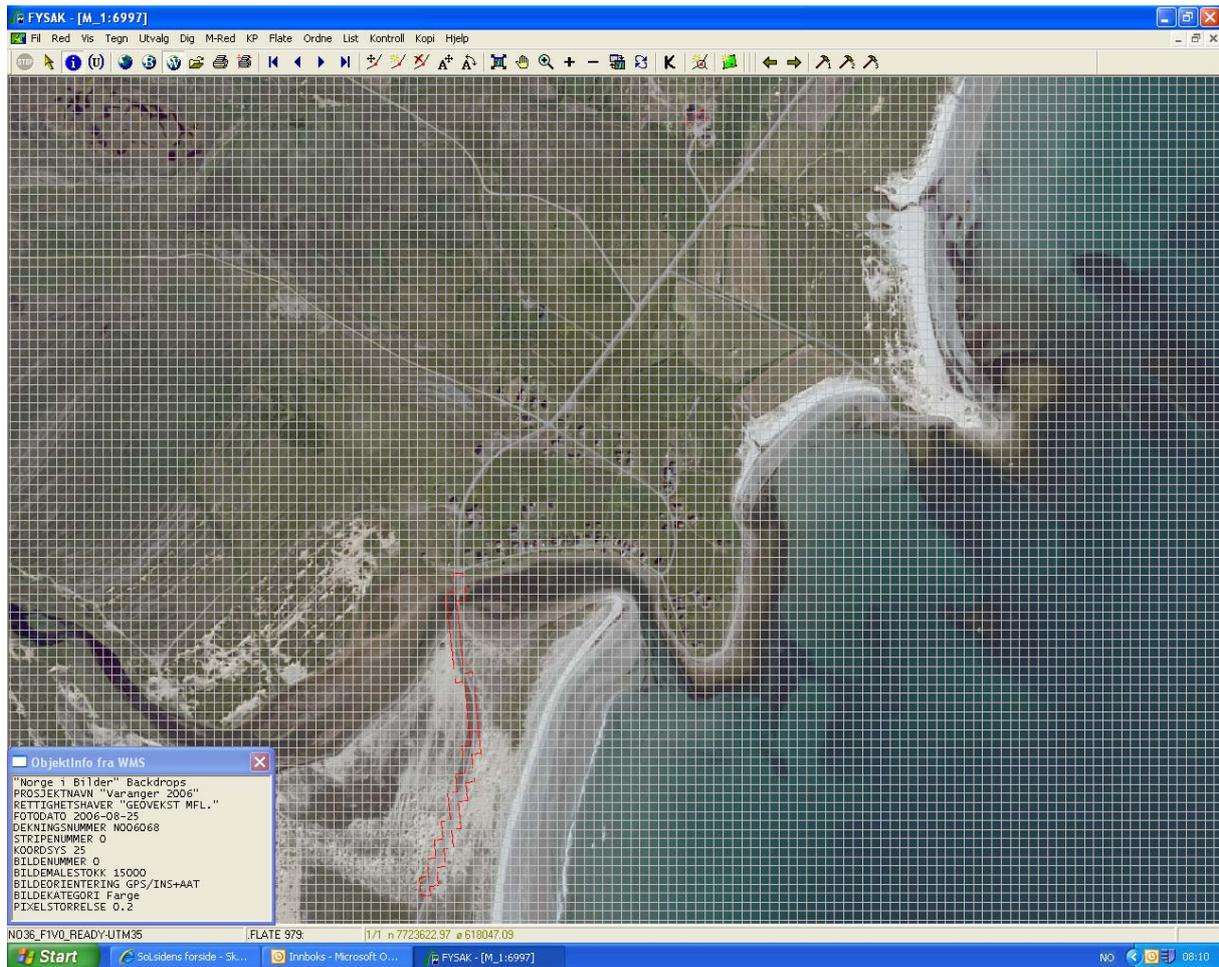
The example shows Oslo Airport Gardermoen. It is partly to confirm the excellent geometry of the HR-SS datasets for Norway, partly to show how well the paved runways are mapped in HR-SS-80

Example A.3: Agricultural land - Rogaland [UTM-32: 327 000, 6 491 600]



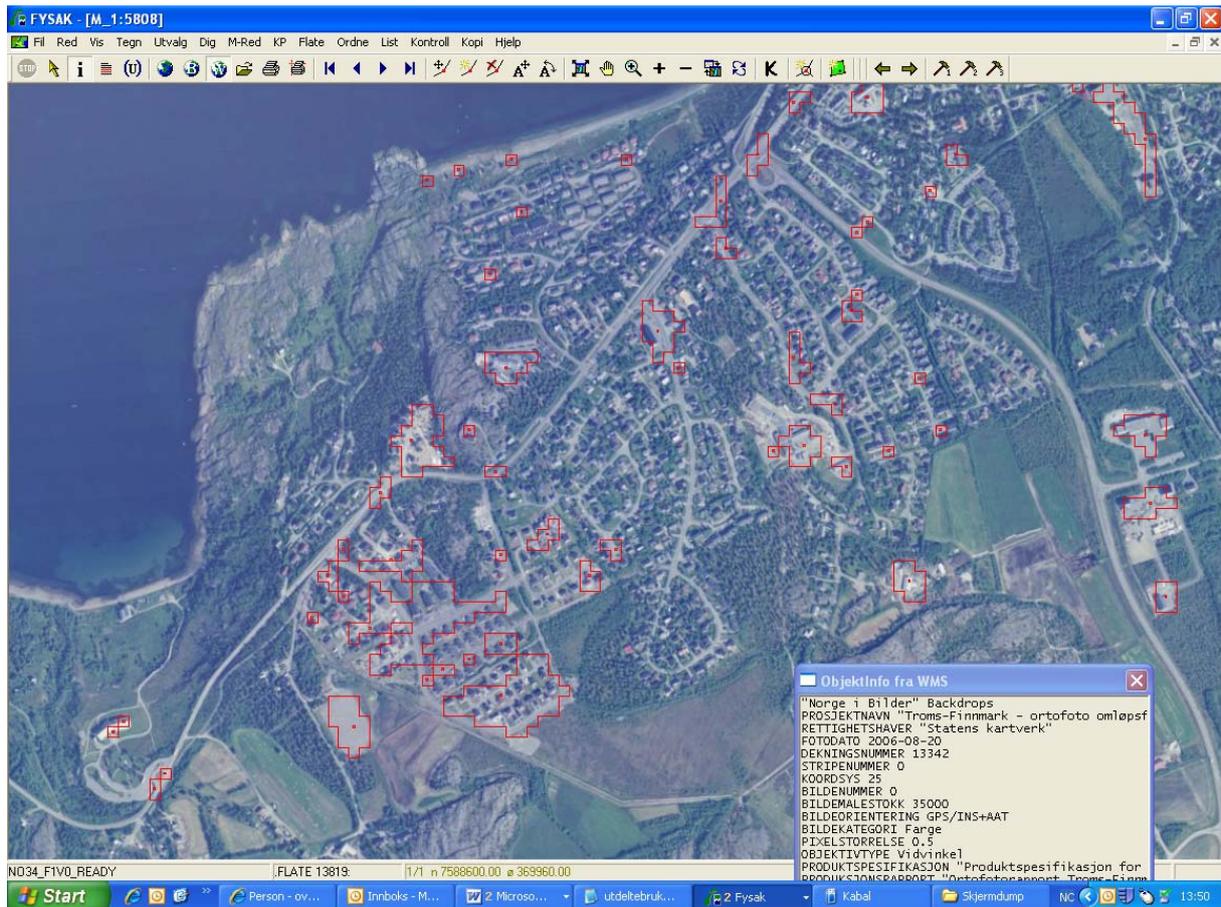
The example shows arable land in southwestern Norway. Only two pixels are “sealed” in HR-SS-80 in this area. It is correct that soil sealing is rare here, but the farmyards contain large buildings and we would have expected a few more pixels mapped as “sealed” in the area. The situation is typical for arable land and heterogeneous agricultural land throughout Norway.

Example A.4: Beach - Varanger [UTM-36:]



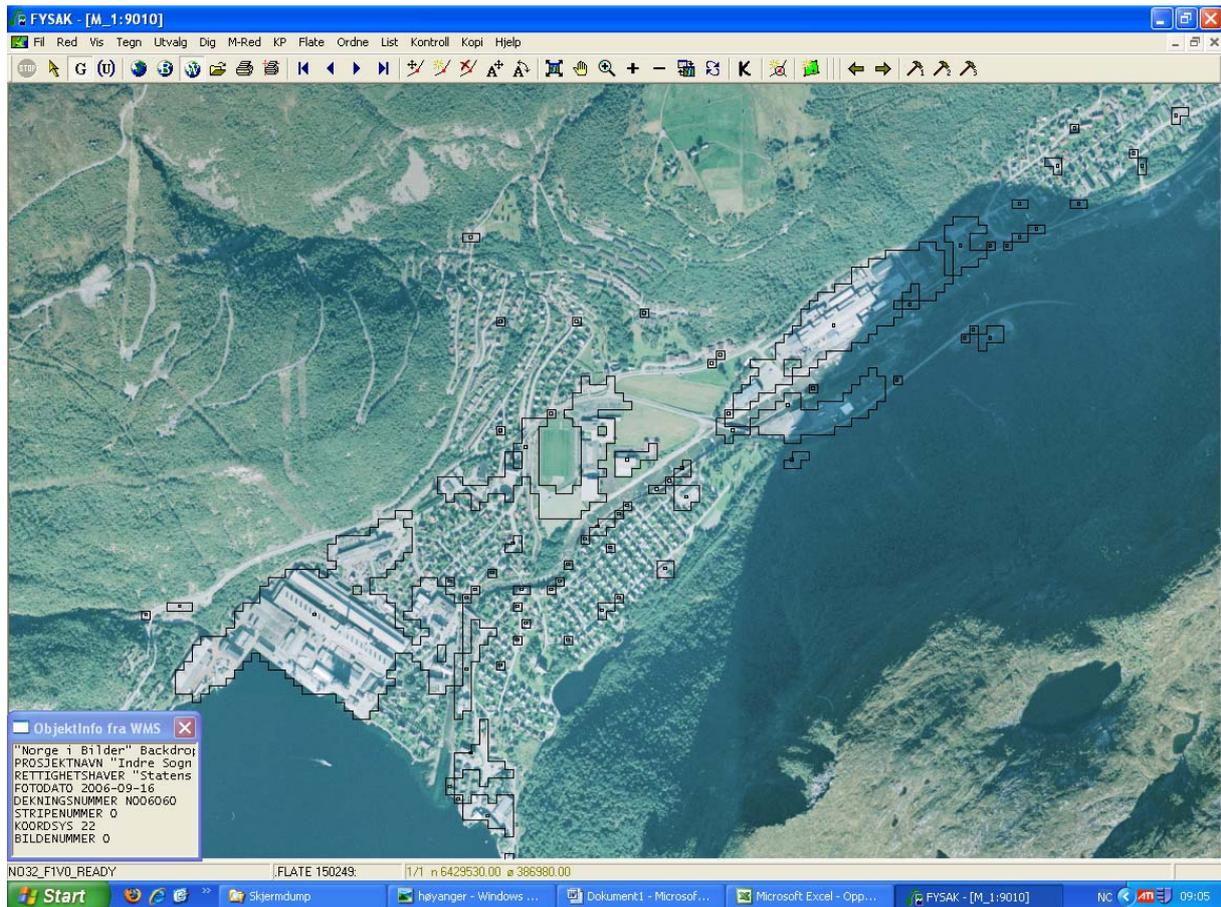
The example shows a beach in northeastern Norway. The beach is correctly mapped as “not sealed”, The road is correctly mapped as “sealed”, but only while passing through the sandy area behind the beach. The road is not mapped as “sealed” while passing through the village on the north bank of the river or through the scrub vegetation found elsewhere in the picture. Many roads along the northern coast and in the high mountains are mapped quite well, probably because there is little or no roadside vegetation in these areas. The mapping of roads is therefore inconsistent. The sealed area resulting from a standard highway is the same irrespective of the vegetation next to the road.

Example A.5: Alta town [UTM-34: 584 300, 7 761 600]



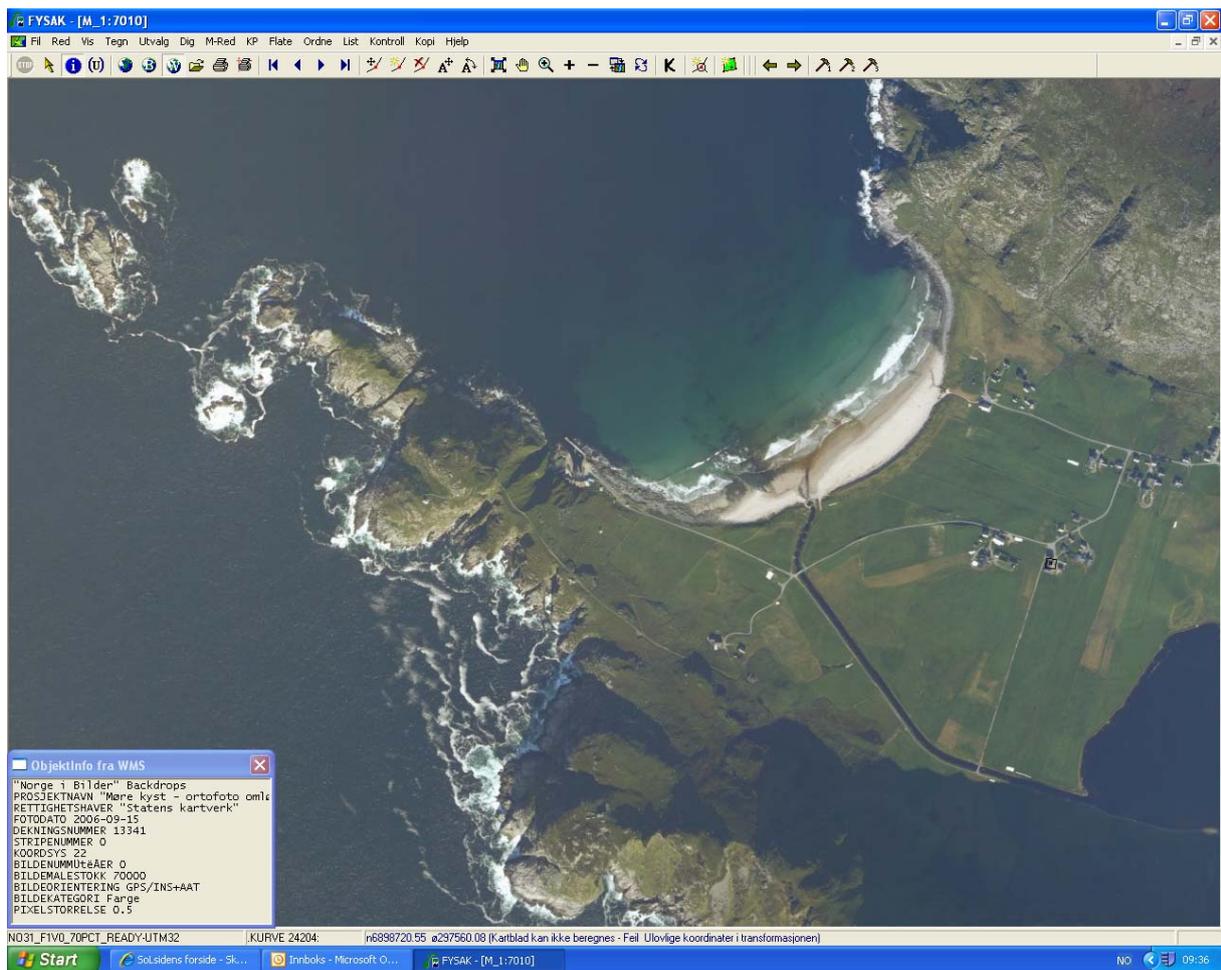
This example from Alta town in northern Norway illustrates some inconsistencies and weaknesses in the mapping of build-up land. Alta mostly consists of single family houses or chained townhouses with surrounding gardens. These are correctly mapped as “not sealed” in HR-SS-80. Road intersections, large parking lots, shopping centers and a few industrial or commercial buildings are mapped as “sealed”. Notice, however, the recently build housing area in the lower left part of the photo. The only difference between this area and other residential areas in the photo is that people living here has not yet made lawns and planted trees around their houses. The area is not more “sealed” than other residential areas, but the vegetation has been temporarily removed and is less developed.

Example A.6: Høyanger industrial plant [UTM-32: 342 500, 6 790 600]



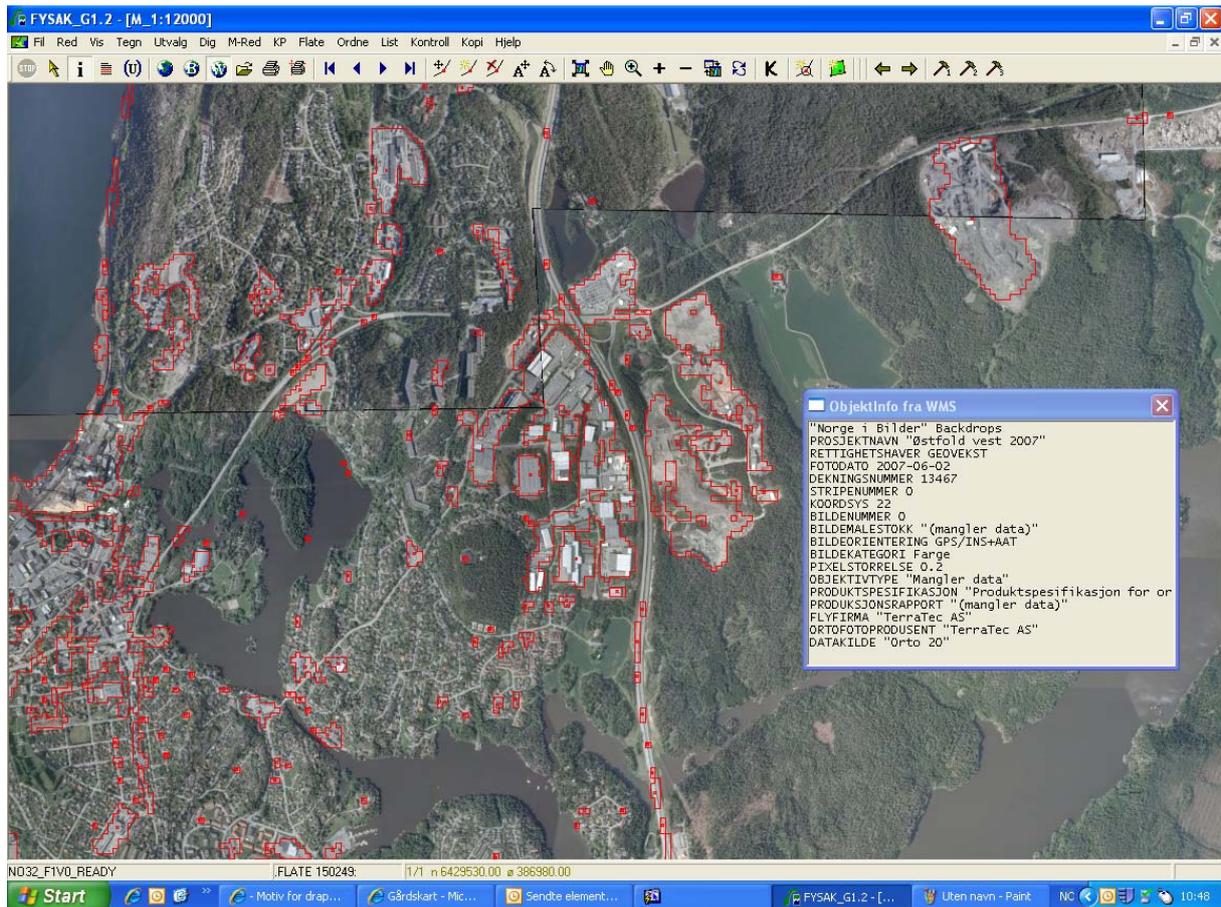
This example shows the Høyanger industrial plant in western Norway and illustrates how the industrial land is correctly mapped as “sealed” while the surrounding residential area with a few irregularities is correctly mapped as “not sealed”.

Example A.7: Beach and heterogeneous agricultural land at Stadt [UTM-32: 297 500, 6 898 500]



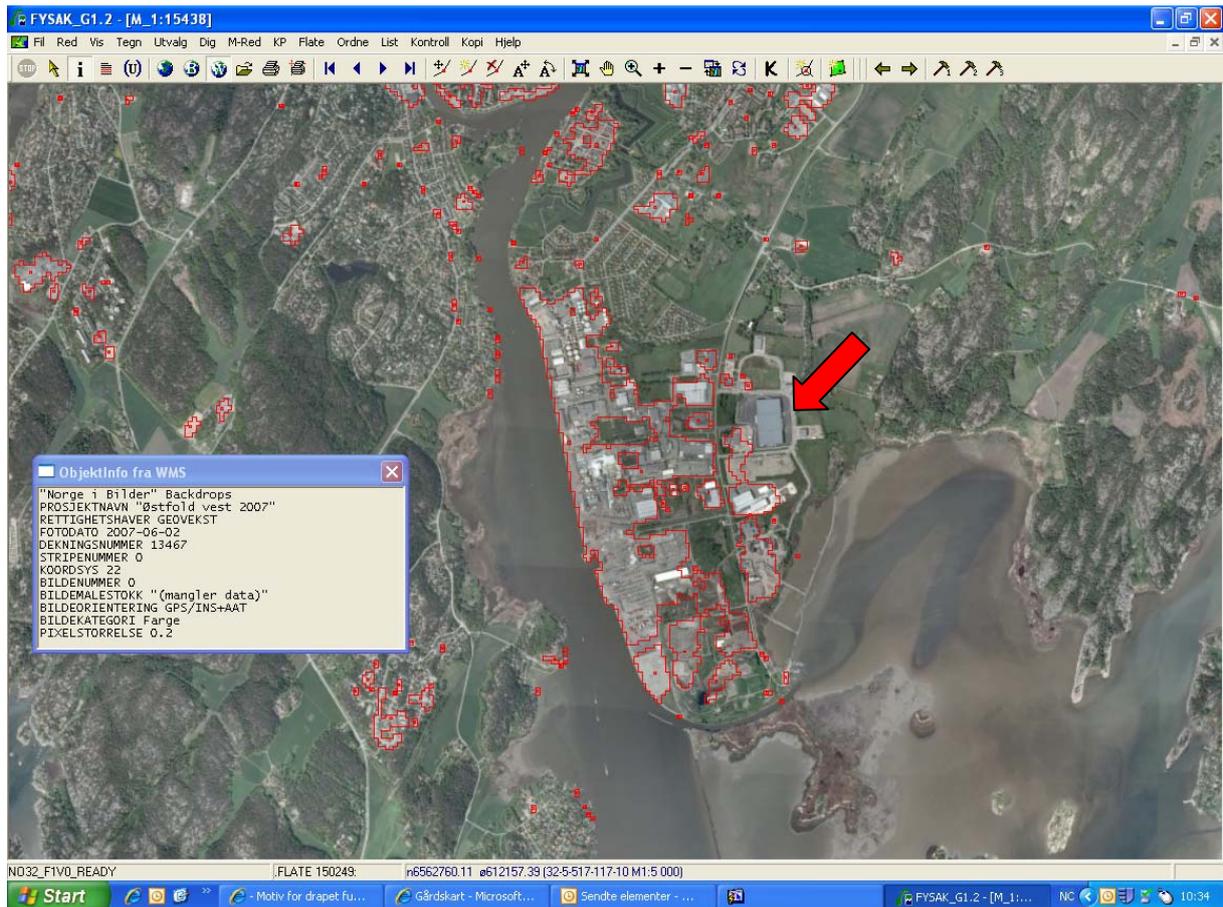
This example shows another sandy beach correctly mapped as “not sealed”. There is a single sealed pixel on one of the farms, but the example again shows that densely built up farmyards are left as “not sealed” in HR-SS-80.

Example A.8: Urban fringe Moss [UTM-32: 596 500, 6 590 900]



This example shows the outskirts of the city Moss in southeastern Norway. The residential areas are mostly mapped as “not sealed” which is correct. The major highway through the area (north-south in the center of the picture) is only partially mapped as “sealed”. This four-lane highway should have been mapped as “sealed”. The surrounding industrial and commercial land is correctly mapped as “sealed”. The quarry and the municipal dump in the upper right corner is, however, only partially shown as “sealed”.

Example A.9: Industrial site Fredrikstad [UTM-32: 612 100, 6 562 200]



This example shows a large industrial area outside Fredrikstad in southeastern Norway. Most of the industrial land is correctly mapped as “sealed”. Notice, however, the building pointed to by the red arrow and the storage are just to the south of this building. The photo was taken in 2007 and the building is quite new (there was a radio antenna here before). It was probably not present when the satellite image used to compile the HR-SS was taken.

Annex B: Photodocumentation of selected areas

A number of areas marked as sealed in HR-SS-80 were inspected on the ground in order to better understand the results; in particular outside densely built up areas. These examples are all located in UTM zone 32. Coordinate reference is provided for identification.

All map examples use the topographic maps from scale 1:50 000 as background. The actual scale in the illustrations may be different from 1:50 000 though. All maps are produced by the Norwegian Mapping Authority (Statens kartverk) and copyright © Norge digitalt.

Example B.1: Julussetra gravel pit [644 300, 6 770 200]



Approximately 75 % of this abandoned gravel pit in a sandy pine forest is marked as “sealed” (grey area in the map). The photo is taken from the southeastern end where the road enters the pit. A number of similar gravel pits in the vicinity are not mapped as “sealed”. The impression is that it is rather random whether these pits appear as “sealed” or not. The pits show considerable regrowth of birch and pine forest.

Example B.2: Godbakken farm [646 400, 6 765 750]



One of the houses, probably the easternmost barn (to the left side of the photo), is represented as “sealed” while the rest of the farmyard is not. This barn has a very dark roof cover. A number of other,

farmyards in the vicinity is not “sealed”. This is shown in the map where a single “sealed” pixel appears on Godbakken farm, while none is shown on the many surrounding farmsteads. The impression is that in the agricultural or heterogeneous agricultural areas, only a few scattered farmyards are randomly mapped as (partially) “sealed” and there is no obvious reason for picking out these single farms. Only Godbakken farm was photographed, but it is very similar to the other farms.

Example B.3: Søndre Bergeberget intersection [649 900, 6 765 700]



The intersections in rural areas (this one along highway R25) are occasionally mapped as “sealed”. The reason is that there is additional hard surface in the intersection where two roads meet. The result is anyhow a random pattern of “sealed” pixels and it does not represent the considerable total areas “sealed” by these roads. In areas where the vegetation has been stripped on the side of the road, sections of the road may also turn out as “sealed”. Generally, only a small part of the road system in rural areas is represented in the map. The percentage is somewhat higher in mountains where there is less vegetation along the roads.

Example B.4: Gravel extraction area in use [651 000, 6 763 000]



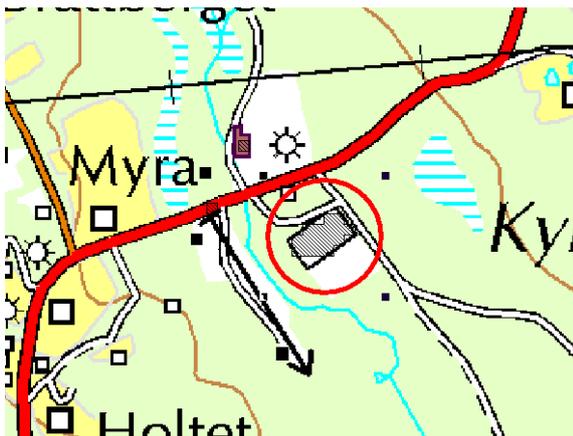
This gravel extraction pit is in active use. Stones are demolished (cracked) and the material is stored in the pit area. The ground is therefore covered with a thick layer of gravel. It seems correct to map this pit as “sealed”. The delineation of the pit is excellent.

Example B.5: Newly abandoned gravel extraction area [649 300, 6 764 800]



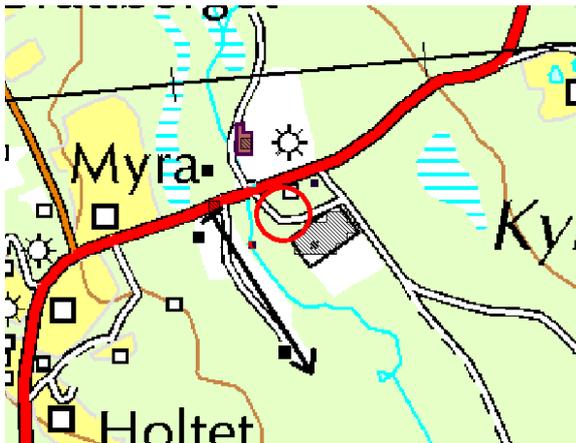
This gravel extraction pit is abandoned but has been in active use until recently. The surface of the area is sand, which is the original material of the area. The delineation of the pit is excellent, but the area is in out opinion not “sealed”, only temporary without vegetation. The pine forest will reclaim the area over the next years. The photo is taken from the top of the pit on the eastern side, towards the road entering from the west.

Example B.6: Soccer field without grass [652 800, 6 760 450]



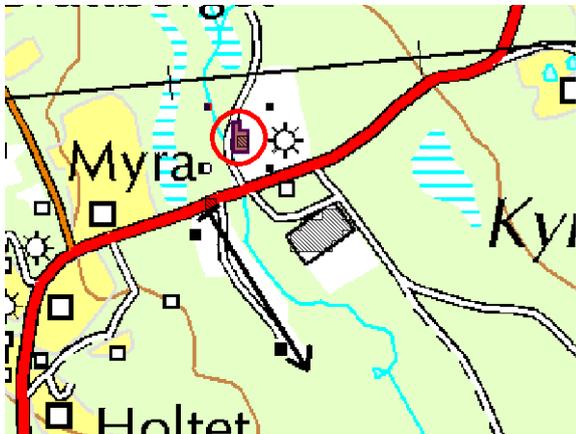
This village soccer field located in a rural area and mostly surrounded by forest, is covered with fine gravel. Although it will be converted back to vegetation if abandoned, it seems correct to map the area as currently “sealed”. The photo is taken from the north-west towards south-east. An additional, grass covered soccer field to the south (not marked on the map but seen with water showers in the back of the photo) is (correctly) mapped as “not sealed”.

Example B.7: Storage area for firewood [652 700, 6 760 600]



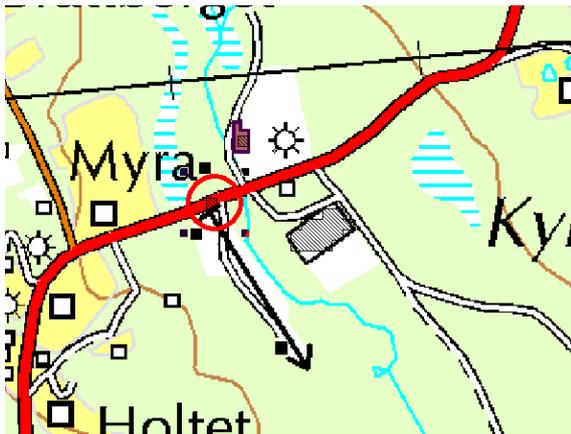
This storage area for (commercial production of) firewood is a gravel covered open space next to the soccer field shown in example B.6 above. The photograph is taken by simply turning the camera 180°. The surface appears to be similar to the surface of the soccer field and the area only slightly smaller. It does not seem correct to map one as sealed and the other as not sealed. We would have expected this area to appear as “sealed”, especially since it covers a 5 or 6 pixels and is next to an area already mapped as “sealed”.

Example B.8: Abandoned saw mill [652 750, 6 760 475]



The building in the center of the photo is marked as sealed ground. Several other buildings and a large storage area (extending behind the building to the right) is not “sealed”. This area is located next to, and has the same gravel covered ground as, the previous two examples. The surface material is seen in the foreground of the photo. The example highlights the problem with smaller, often rural industrial sites with small buildings and where the ground is not paved. The classification is not necessarily wrong, but whether this is sealed land or not is dependent on a more detailed definition of “sealed land”.

Example B.9: Shooting range [652 625, 6 760 485]



The leftmost part of the roof covering the firing area of this rifle shooting range is marked as sealed. Mapping only part of the building seems wrong. It is also inconsistent when large barns on the surrounding farms (see the left hand part of the map) have not been mapped as sealed.

Example B.10: Flats for elderly people [650 675, 6 759 670]



This building containing flats for elderly people has been mapped as "sealed". A nearby school and a community dance hall (next two examples) are also "sealed". A number of surrounding farms with large barns are not sealed. The example adds to the general impression of inconsistent mapping in the rural areas.

Example B.11: Sørskogbygda primary school [650 600, 6 759 600]



This school, with a flat, black roof is mapped as sealed. The delineation of the building is remarkably accurate. Surrounding parking lots (gravel, not asphalt) are not “sealed”. The soccer field seen on the map but slightly outside the right edge of the photo, is covered with grass and correctly mapped as “not sealed”.

Example B.12: (Road in front of) community dance hall [650 475, 6 759 600]



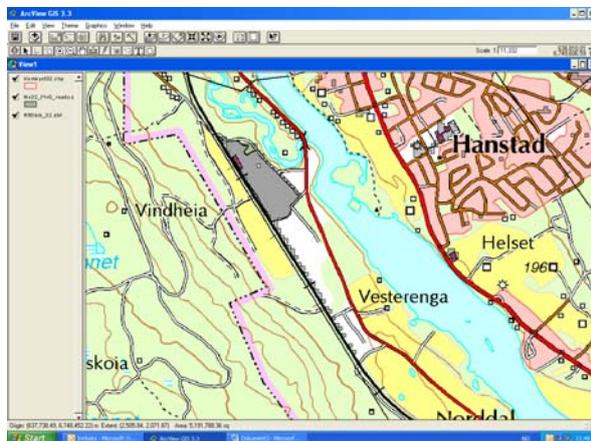
This community dance hall and the parking lot on the left side and behind are not mapped as sealed. The road in front is, however, sealed. The road is probably “sealed” because the road together with the entrance to the dance hall has the same effect as an intersection with extra pavement added to support driving off the road to enter the parking lot around the dance hall. The dance hall is somewhat smaller than the school next door (example B.11) but still large enough to expect it to appear as “sealed” land. The surrounding parking lot is covered with gravel, but no less “sealed” than the soccer field from example 6, located only two and a half kilometers away.

Example B.13: Petrol station [645 000, 6 758 250]



This petrol station is represented as two pixels of sealed area. The building itself is considerably larger. In addition, at least one ha around the building is covered with asphalt, and an even larger area covered by processed gravel (as in several of the examples above). We would expect at least 25 pixels of sealed area here. Also notice that the intersection in the map which is not marked as “sealed”, although it is very similar to the intersection mapped as “sealed” shown in example 3.

Example B.14: Storage area for timber [638 500, 6 750 000]



Approximately 50 % of this large storage area for timber is marked as sealed. We do not know how much timber was present at the time when the satellite photo was taken. The ground is covered with gravel. The leftmost ortophoto shows the part of the area marked as “sealed” in HR-SS-80. The northernmost part also contains a few buildings for equipment. An ortophoto taken 1 August 2002 further illustrates the situation. The leftmost ortophoto shows the northern part of the area (marked as “sealed” in HR-SS-80) while the rightmost ortophoto shows the southern part of the terminal (marked as “not sealed” in HR-SS-80). Whether this area is “sealed” or not can be discussed. It is sealed under the temporary use, but will be reclaimed by forest if abandoned. .More important is the inconsistency between the mapping of the northern and the southern part of the area.

Example B.15: Elverum village [639 000, 6 752 600]



This small town is an example of how HR-SS-80 performs in densely built up areas. The red arrow in a black circle marks the position and direction of the camera. The central part of the town, with larger commercial buildings, roads and parking lots are mapped as “sealed” while parks and the surrounding suburbs with single family houses in gardens are “not sealed”.