©1983 Geologie en Mijnbouw 0016-7746/83/6204-0611 $ 2.50/0

DETAILED SYSTEMATIC GEOMORPHOLOGICAL MAPPING IN THE NETHERLANDS AND ITS APPLICATIONS[1]

J. A. M. TEN CATE[2]

ABSTRACT

Ten Cate, J. A. M. 1983 Detailed systematic geomorphological mapping in The Netherlands and its applications. In: J. H. J. Terwindt & Van Steijn (eds): Developments in physical geography – a tribute to J. I. S. Zonneveld – Geol. Mijnbouw 62: 611-620.

Detailed systematic geomorphological mapping in The Netherlands started in 1966. Since 1975 these maps have been printed in colour. This paper describes the structure of the legend of the 1:50000 geomorphological map of The Netherlands and discusses the practical applications. These include geological and soil surveys, the conservation of important localities of earth science interest, the execution of multidisciplinary projects and mappings for contractors.

INTRODUCTION

In the last twenty years considerable progress has been made in detailed geomorphological mapping in many countries and in producing a system of symbols and colours related to the portrayal of the evolution, the resultant forms and the age of the units of the geomorphological landscape, using map scales between 1:10000 and 1:250000 (GILEWSKA, 1967; VAN DORSSER & SALOMÉ, 1973). This is mainly due to the work of the Commission on Geomorphological Survey and Mapping of the International Geographical Union (DEMEK, 1972; DEMEK & EMBLETON, 1976).

In 1966, at the suggestion of Prof. G. C. Maarleveld (TEN CATE ET AL., 1981b), The Netherlands Soil Survey Institute in Wageningen and the Geological Survey of The Netherlands in Haarlem decided to start a systematic geomorphological mapping of The Netherlands on a scale of 1:50000. This kind of map was intended to aid and accelerate soil and geological mapping. From 1966 until the end of 1970, fifteen provisional geomorphological maps were produced (but not printed). Several institutes, e.g. those for national and regional planning and for conservation of the natural and cultural landscape showed an interest in these maps. This was the main motive behind the decision in 1971 to start printing them.

Up to the end of 1974 much time was devoted to setting up a legend suitable for the whole country. In the legend of the fifteen unpublished maps the surface forms were classified according to relief building forces and geomorphological processes. This caused many problems because the genesis of the forms is often very complex. Two important factors responsible for this complexity are the human influence (especially in the westerly Holocene part of The Netherlands) and the common presence of a coversand layer of varying thickness (in the easterly Pleistocene part of The Netherlands) sometimes masking, sometimes accentuating underlying forms. Furthermore the genesis of some forms is only poorly known and little time is available for in-depth examination because four maps need to be produced every year. In view of this, it was decided to draw up a legend in which information about relief and form (based on direct observation) is indicated on the highest level, while information about genesis (often of a more or less hypothetical nature) is indicated on a lower level.

To obtain some idea of the various kinds of forms and their genesis and of the requirements for a legend for large-scale geomorphological maps in The Netherlands, and to comply with requests to compile small-scale maps, two maps were composed according to the above-mentioned principle (MAARLEVELD ET AL., 1974; MAARLEVELD, 1975).

---

[1] Manuscript submitted: 1983-03-01.

[2] Soil Survey Institute, P.O. Box 98, 6700 AB Wageningen, The Netherlands.

In 1975 two large-scale maps were printed together with the unified key for all 1:50000 geomorphological maps of The Netherlands (MAARLEVELD ET AL., 1975). However, this legend, printed on one sheet, was not considered to be a final one. Criticism and suggestions have been taken into account for the final edition of the legend, which was published together with an explanation to the legend in book form (MAARLEVELD ET AL., 1977; TEN CATE & MAARLEVELD, 1977).

MAIN ELEMENTS OF THE 1:50000 GEOMORPHOLOGICAL MAP OF THE NETHERLANDS

The basic criteria used as the framework for more specific representation of landforms are those of relief classes and form groups. Eight *relief-classes* are distinguished, defined by maximum angle of inclination and length of slopes. This primary division is combined with an independent classification of eighteen *relief-subclasses* defined by maximum relative height differences (Table 1). *Form groups* are recognized on the basis of more qualitative definitions of relief geometry. They include plateaus, groups of hills, fan-shaped forms, plains, etc. (Table 1). Each form group in its turn is subdivided into *form units* according to form and genetic considerations. Thus 'Terrace forms' are separated into eleven form units, e.g. 'fluvio-glacial terrace with a layer of coversand, gently undulating'; 'structural terrace partly covered with loess'; 'valley-plain terrace' and 'valley-plain terrace with a layer of coversand, almost flat'.

The code of each legend-unit indicates relief subclass, form group and the genetic-morphological name of each form unit. The mosaic of colours conveys the genetic classification. The symbols indicate certain form groups. The intensity of the colours and the boldness of the symbols are an expression of the relief. The morphochronological dimension is considered with a specially constructed legend plotting the ages of every form unit according to a simple five-fold division ranging from Pre-Quaternary to Recent. In the same way, a comprehensive morphogenetic classification according to a nine-fold division, such as tectonic, aeolian, fluviatiele and organic, is given.

Information about the lithology of the landforms is represented in an indirect way. The morphogenetic name quite often reveals the lithology, e.g. coversand ridge, tidal accumulation plain, beach plain partly with low dunes, peat plain under cultivation sometimes covered with a thin clay or sand layer, ground-moraine plain. Detailed lithological information can be found on the geological and soil maps of The Netherlands. The 1:50000 geological map describes the lithology to a depth of four to ten metres. Still more detailed information of the upper 1.20 m is indicated on the soil map, also using a scale of 1:50000 (Table 2).

Fig. 1 shows the progress made in geomorphological mapping. The legend system developed for the 1:50 000 geomorphological map has become a basis for later geomorphological surveys carried out by other institutes. By closing the sea entries in the southwestern part of The Netherlands. the morphology of the salt marshes, intertidal flats, etc. in the estuaries will change. These changes can already be observed. In a report published by the Department of Public Works (BUYSROGGE ET AL., 1982) geomorphological maps of emerged areas in the former Grevelingen estuary are presented using a 1:10000 scale. In the legend to these maps the main elements are also relief classes, form groups subdivided into form units and a morphogenetic classification. More examples are the geomorphological maps 1:25000 of several parts of the north-

Table 1

Classification of relief and landforms

RELIEF

Relief classes		Relief subclasses
	Areas with little relief	
I	Flat areas	1 and 2
II	Almost flat low areas	3 up to 6
III	Almost flat high areas	7 up to 9
	Areas with pronounced relief	
IV	Relief with short gentle slopes	10 and 11
V	Relief with very short steep slopes	12 and 13
VI	Relief with long gentle slopes	14 and 15
VII	Relief with moderately short steep slopes	16 and 17
VIII	Relief with long steep slopes	18

LANDFORMS

Form groups		Form units
A	Slopes	1 up to 3
B	Isolated high hills, ranges of high hills and high dike-like forms	1 up to 13
C	High hills and ranges of high hills with associated plains and lower areas	1 up to 4
D	Plateaus	1 up to 3
E	Terrace forms	1 up to 11
F	Plateau-like forms	1 up to 12
G	Fan-shaped forms	1 up to 7
H	Slightly inclined surfaces	1 up to 14
K	Isolated low hills, ranges of low hills, low ridges and low dike-like forms	1 up to 36
L	Low hills, ranges of low hills and low ridges with associated plains and lower areas.	1 up to 22
M	Plains	1 up to 48
N	Closed depressions	1 up to 10
R	Shallow valleys	1 up to 14
S	Moderately deep valleys	1 up to 7
T	Very deep valleys	1 up to 5

Table 2

Main items directly (x) or indirectly (0) indicated on the Geological, Geomorphological and Soil Map of The Netherlands, scale 1:50 000

Items	Geological map	Geomorphological map	Soil map
Lithology	x	0	x
Age	x	x	
Genesis	x	x	0
Morphology		x	
Morphometry		x	
Soil profile			x
Groundwater level			x

ern provinces of The Netherlands (WIJNHOVEN ET AL., 1979) compiled at the request of the Ministry of Economic Affairs. This survey was part of an environmental mapping project for the development of the northern provinces. Even the legend of the geomorphogenetic map of 'Zuid Utrecht' in the central Netherlands using a scale of 1:25,000 by BERENDSEN (1982) in his thesis written under supervision of Prof. J. I. S. Zonneveld was influenced by the legend system developed for the systematic geomorphological map of The Netherlands. By adding lithological information, strongly related to the morphology, this map together with the legend, indicates the direction to more integrated surveys.

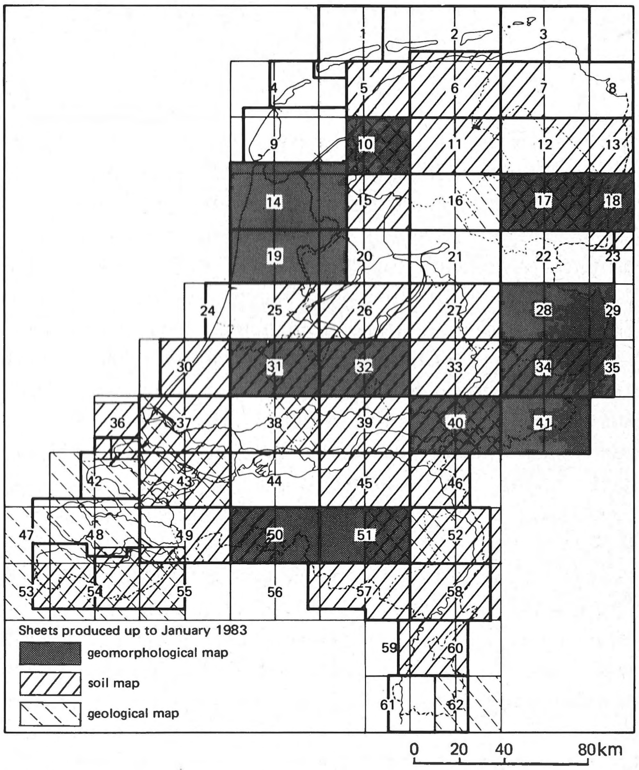


Fig. 1
The progress made in geomorphological, geological and soil mapping of The Netherlands, scale 1:50000.

THE USE OF GEOMORPHOLOGICAL MAPS IN GEOLOGICAL AND SOIL SURVEYS

The geomorphological maps give the geologist an overall view of the area to be mapped. Information about the configuration of the terrain and distinct phenomena related to the genesis, visible in the field, can easily be read from these maps. Frequently the slopes, the differences in height and the age of the form are closely related. Thus, during the mapping in the central Netherlands (TEN CATE, 1969; MAARLEVELD, 1973) most of the coversand ridges were found to be less than 1.5 m higher than their immediate surroundings. The slopes of these ridges are gradual; hardly any slope was steeper than 5°. The material of these ridges consists of more or less horizontally bedded moderately fine sand, Younger Coversand I, from the Early Dryas age. In places where ridges are higher than 1.5 m (Fig. 2) this coversand is overlain by up to 1 m of moderately fine sand, Younger Coversand II, from the Late-Dryas age (part of the Weichselian's Late Glacial). In such cases, the slopes of the ridges are steeper than the Early Dryas ridges.

As expected, the lithological boundaries correspond closely to the horizontal extent of the landforms. Thus, the geologist can obtain important information from the landforms delimited on the geomorphological map, together with their slopes and differences in height. Furthermore, the geologist can often indicate sites for drillings more successfully after consulting the geomorphological map. The soil surveyor benefits from the geomorphological map in a similar way. Soil profiles frequently correlate with geomorphological configuration; this is intensified by the modelling processes they share. The relation between depth of the groundwater level (in classes) and the differences in height of surface forms is evident.

In the field, geological and soil boundaries frequently correspond with boundaries of landforms but we can observe considerable differences on the three maps. It was found (TEN CATE ET AL., 1981a) that variations in survey methods, effectiveness of the legends and the varying aims and starting-levels of the three disciplines within earth sciences are the cause of the differences in boundaries on the geological, soil and geomorphological maps.

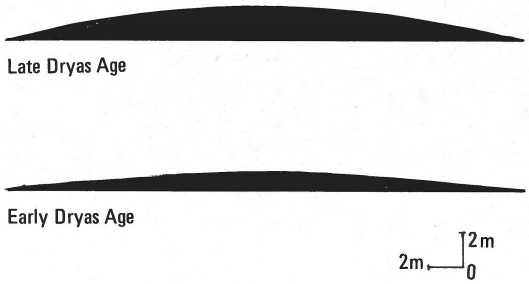


Fig. 2
Cross-section of a typical cover-sand ridge from the Early Dryas Age and from the Late Dryas Age in the central Netherlands. Note the difference in height (after Maarleveld, 1973).

GEOMORPHOLOGICAL SURVEY AND THE CONSERVATION OF IMPORTANT LOCALITIES OF EARTH SCIENTIFIC INTEREST

In the past, the protection of areas of geological, geomorphological and pedological value has not received sufficient attention from geologists, geographers and soil scientists. Up to the end of the sixties only eleven reserves have been protected specifically for their earth scientific interest since establishment of the first one, 'the Naardermeer' in 1906. However, in 1969 a working group named 'Gea' was set-up to carry out a long-term project dealing with the protection of localities important to the earth sciences. The Gea project aims to safeguard sites of geological, geomorphological and pedological interest that reflect the genesis of The Netherlands, taking into account aesthetic, scientific, ecological, educational and recreational considerations (GONGGRIJP, 1977).

The first inventory to be completed was for the province of Overijssel in the eastern part of The Netherlands. This inventory includes sixty-one selected sites, among them geological sequences, type-localities, geomorphological systems and soil profiles. So far, the survey of six of the eleven provinces has been completed and published. Besides these provincial inventories attention has been paid to more than twenty sites, all over the country, threatened with destruction (GONGGRIJP & BOEKSCHOTEN, 1981). One example is the area situated just south of the town of Roermond at the confluence of the small river Roer and the Meuse (Fig. 3). The 'Present Roer system' typifies the valleys of the small meandering rivers that occur in the slightly undulating Pleistocene part of The Netherlands. There are similar systems in the eastern and southern part of the country. The 'Old Roer system' is a fossil river system of Weichselian age but it is not the only one in the country. However, the other fossil river systems are braided, while the 'Old Roer system' shows a clear meandering pattern.

GEOMORPHOLOGICAL SURVEYS IN MULTIDISCIPLINARY PROJECTS

During the last ten years the demand for environmental information about different areas has increased. To obtain sufficient detailed and accurate data, close cooperation between different disciplines has been necessary. During the first survey stage, work has often been done along parallel but independent lines.

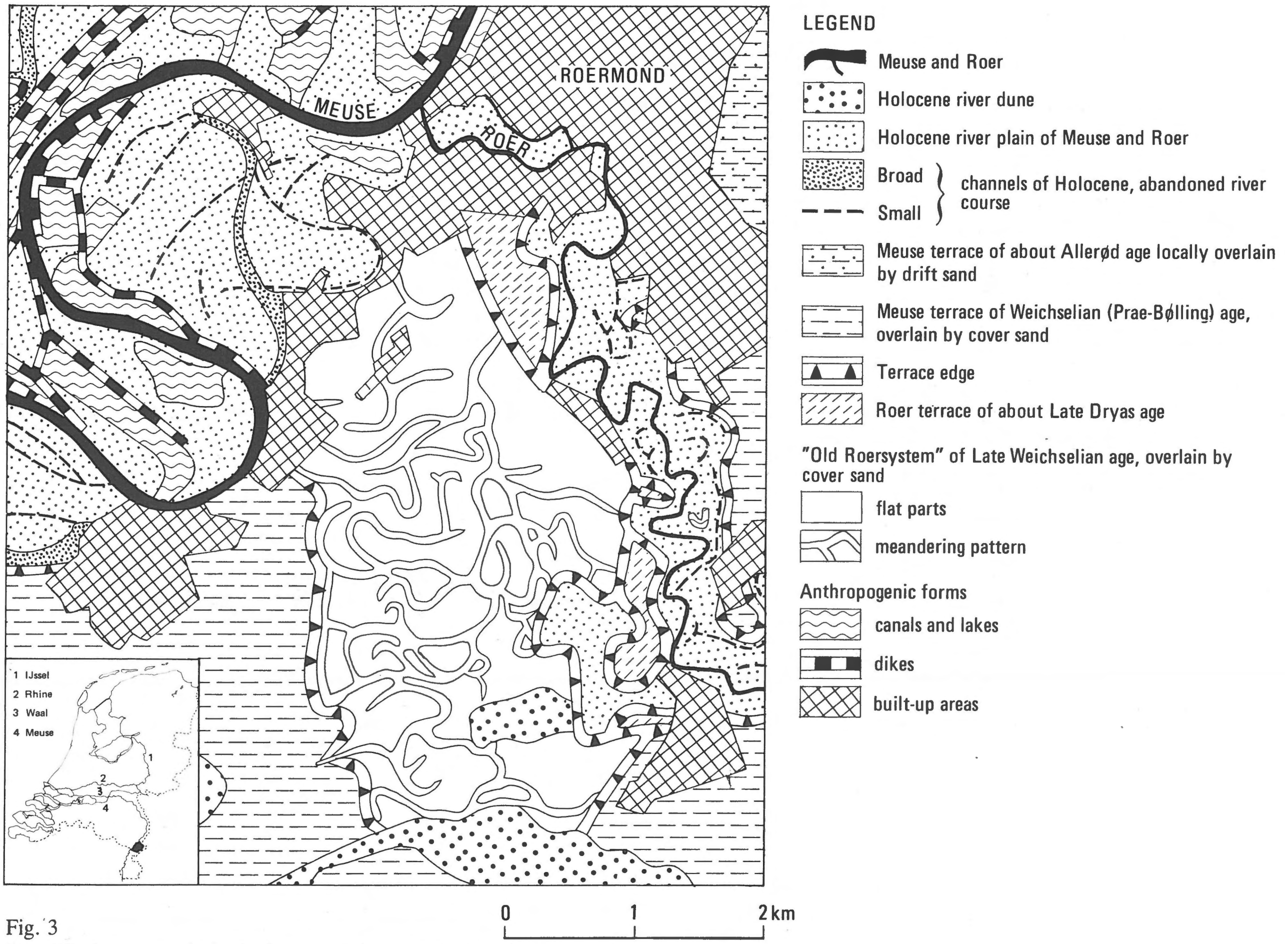


Fig. 3
Simplified geomorphological map of the area south of the town of Roermond.

The second stage, evaluation, also requires close cooperation. Parameters often used in evaluation include:

Rarity: In nature every element is essentially unique. To use rarity as a parameter we need to make generalizations and classify them.
The practical significance of such a classification is in fact that of a warning system indicating the urgency for conservation.

Soundness: The impact of human activities on natural elements is important and often irrevocable. Classification according to soundness (a relative measure of the degree to which an element has been interfered with) is arbitrary, but nonetheless necessary.

Quality: This parameter indicates how representative the element is of its type (i.e. how perfect it is). Thus 'very high' quality means that all the distinguishing features of the type of element are present.

Abundance: Size or number of an element in an area.

Diversity: The number of different elements in an area.

The River Foreland Project

The forelands of the rivers IJssel, Rhine, Waal and Meuse belong to the most valuable natural environments of The Netherlands, the half-natural landscapes, where the influence of man is limited and that of the river strong. The forelands are predominantly uninhabited pastures, mainly used as hay-fields or grazing land. With the exception of the higher parts, they are exposed to inundations every year (Fig. 4). Economic activities such as extracting clay for bricks conflict with ecological and environmental conservation in the forelands. The area concerned is 38000 ha.

The project started in 1970. It aims to classify objectively the natural and environmental values of each river. Within the zone bordered by the river and outer dike, 212 areas have been distinguished and classified as very high, high, moderate and low value. The map scale is 1:50000 for the inventories and 1:100000 for the evaluation of aspects. Two maps (scale 1:100000) present the final evaluation. Inventories and evaluations were made of geomorphology, landscape, botany, ornithology, hydrobiology and zoology. In the final evaluation, hydrobiology and zoology were not considered because of lack of manpower.

The inventory refers to relevant parameters such as diversity, abundance, rarity, quality and soundness. Each discipline requires its own method of inventory and evaluation. The geomorphology and landscape physiography of each river are so different that the inventory, evaluation and integration were made separately for each one. The results of this investigation enable planners to compare one area with another when a decision is to be made about activities in the foreland. Thus, the investigation is a policy-making instrument (DE SOET, 1976).

Lack of time prevented the geomorphology from being mapped using the same legend as the systematic 1:50000 geomorphological map of The Netherlands. The main difference is that indications of relative differences in height and information on slopes have been omitted.
The resulting so-called simplified geomorphological map, printed in colour like the other maps of this project, has 44 legend units (MAARLEVELD & DE LANGE, 1972). Part of this map is presented in Fig. 5a. The morphology in the forelands is shown in detail; outside the forelands only larger units are indicated. The evaluation of the same area is shown in Fig. 5b.

The Veluwe Project

The Veluwe, an area of 120000 ha in the central Netherlands (Fig. 6), has a varying topography and is one of the most valuable natural environments of the country. Various kinds of human activity (such as the construction of new roads, the metalling or improvement of old roads, increased use for military purposes, and particularly the siting of camping and recreation areas) meant an increase in environmental interference. This led the Ministry of Cultural Affairs, Recreation and Social Welfare to request an investigation in this area. The aim of the investigation, which incorporated the assistance of several institutes, was to gather information to counter further interference with the natural environment. The pro-

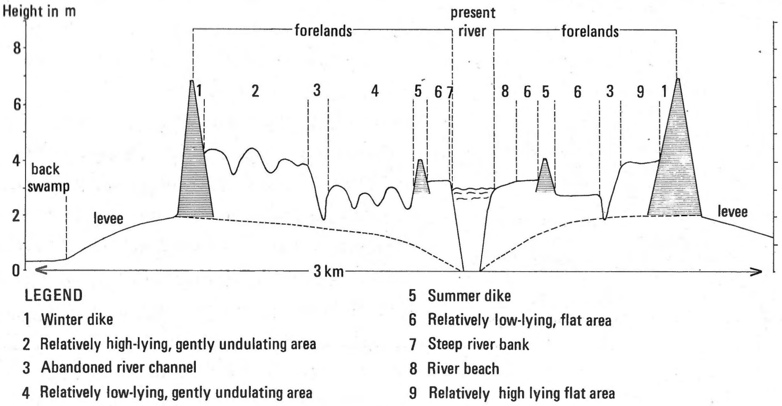
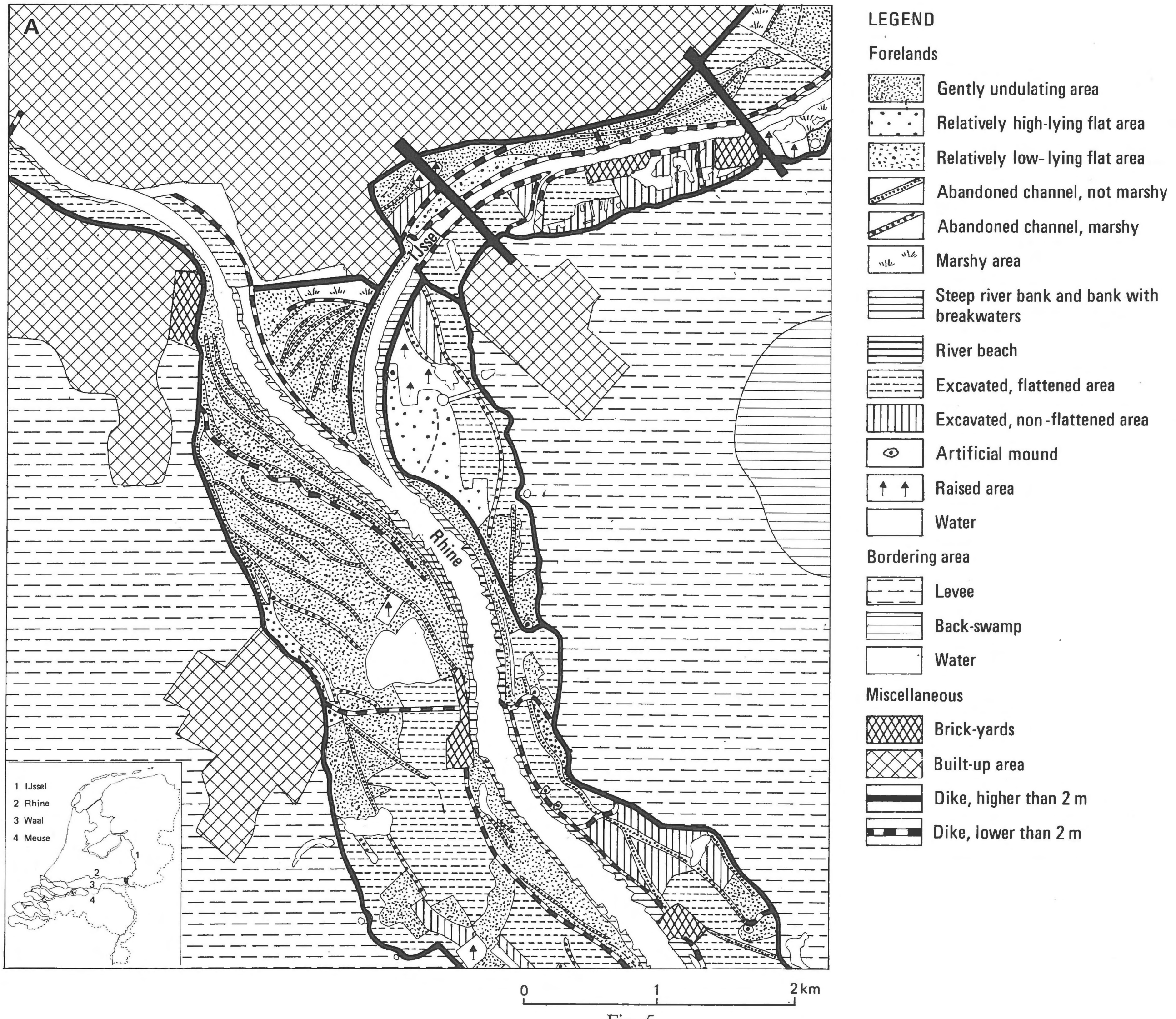


Fig. 4
Schematic cross-section through the forelands of a river in The Netherlands (the forelands are between the winter dike and the river).



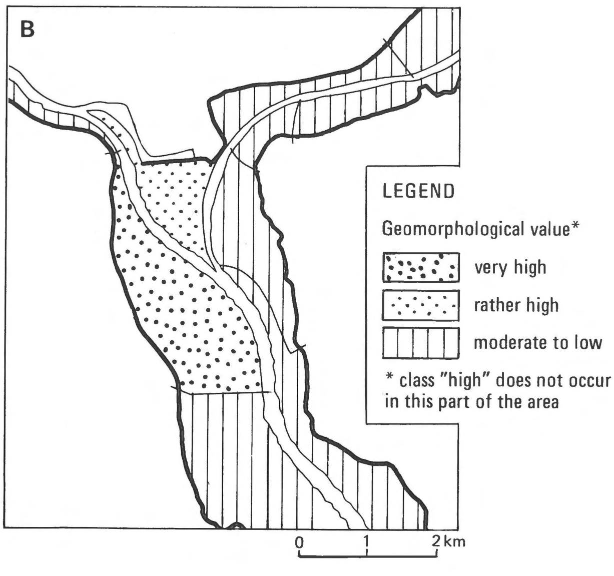
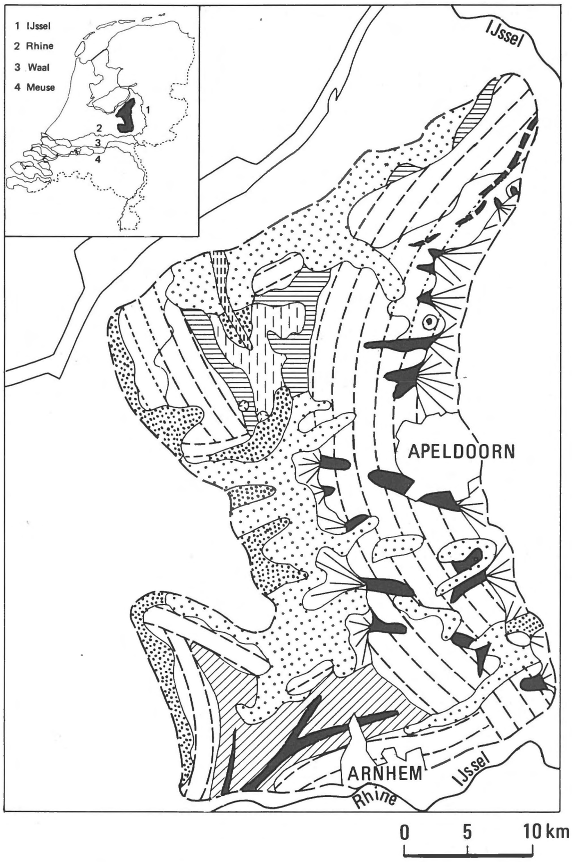


Fig. 5
A (top). Simplified geomorphological map of the forelands south of Arnhem.
B (left). Geomorphological evaluation of the same area (according to Maarleveld & De Lange, 1972).

ject started in 1972 with a strongly analytical approach. Inventories were made of abiotic as well as biotic and human aspects: geomorphology, pedology, vegetation, forest-types, wildlife, cultural history, anthropogenic influences, hydrology of surface water- and landscape-physiognomy.

The information collected, with the exception of wildlife resources, was put on maps at a scale 1:100000. To facilitate interpretation, the Veluwe was divided into 97 roughly equal areas according to important roads, geomorphology and landscape (TEN HOUTE DE LANGE, 1977). For each area the following characteristics were indicated: description (what kind of qualities are present), evaluation (of qualities for each aspect and for all the aspects combined) and vulnerability (for each aspect the effects of several kinds of recreation on the qualities).



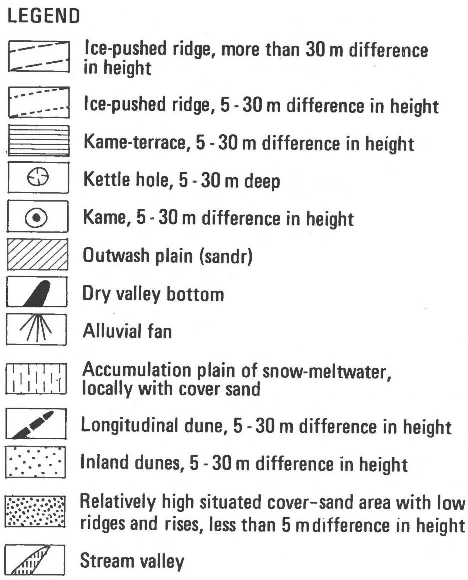


Fig. 6
Geomorphological sketch-map of the Veluwe.

The legend of the 1:100000 geomorphological map of the Veluwe (MAARLAND & DE LANGE, 1977) is very similar, though of course less detailed, to that used for the systematic geomorphological map of The Netherlands scale 1:50000. The map shows the morphology, morphometric elements and genesis of the landforms. The evaluation refers to the quality, rarity and soundness of the 43 legend units in the 97 areas and has been indicated in five classes varying from very high to low. The vulnerability of the landforms to damage caused by recreation was estimated by assessing direct changes to the morphology (excavations, disturbed areas, etc.) on the one hand, and by assessing indirect changes (destruction through wind and water erosion, etc.) on the other.

Project of national highway number 15 near the town of Oldenzaal

At the request of the Ministry of Transport and Public Works in 1976, several institutes assisted in determining a road-plan, part of national highway number 15 in the east of The Netherlands (Fig. 7).

A choice had to be made between two alternative routes 01 and 02, through or around the town of Oldenzaal. This study has been published in a report (RIJKSWATERSTAAT, 1976) explaining the effects each alternative route would have on the area. This report is also a valuable example of the methods used to evaluate natural environments.

Lack of time necessitated the use of existing maps. Only a few supplementary investigations were carried out. The alternatives 01 and 02 were compared regarding their functions and aspects (see Table 3). From these elements an information matrix was constructed, using methods developed in the U.S.A. (LEOPOLD ET AL., 1971) to evaluate environmental effects from a purely informational matrix-system. For each element the impact (quality) and extent (quantity) of the disturbances were scored. This procedure precluded awarding any importance to the mutal influence of the elements.

Weighting therefore did not take place as this is more a matter of policy for the authorities. Using a scale ranging from A to E, Table 3 shows, as objectively as possible, the intensity of disturbance of the elements. To indicate whether the disturbance is local or affects large parts of the road-plan, it was rated according to a scale ranging from 1 to 5. Finally, the construction costs of each alternative have been indicated.

The geomorphology of the area can be summarized as follows:

Most of the area consists of an ice-pushed ridge (Fig. 7a) on which the towns Oldenzaal and De Lutte are partly situated. On the western flank of this ridge there is a layer of coversand. The terrain is quite flat here. Snow meltwater flowing over permafrost, mainly during the Weichselian, has eroded valleys in this ridge. The valley heads are often slight depressions which have developed into characteristic flat-bottomed val-

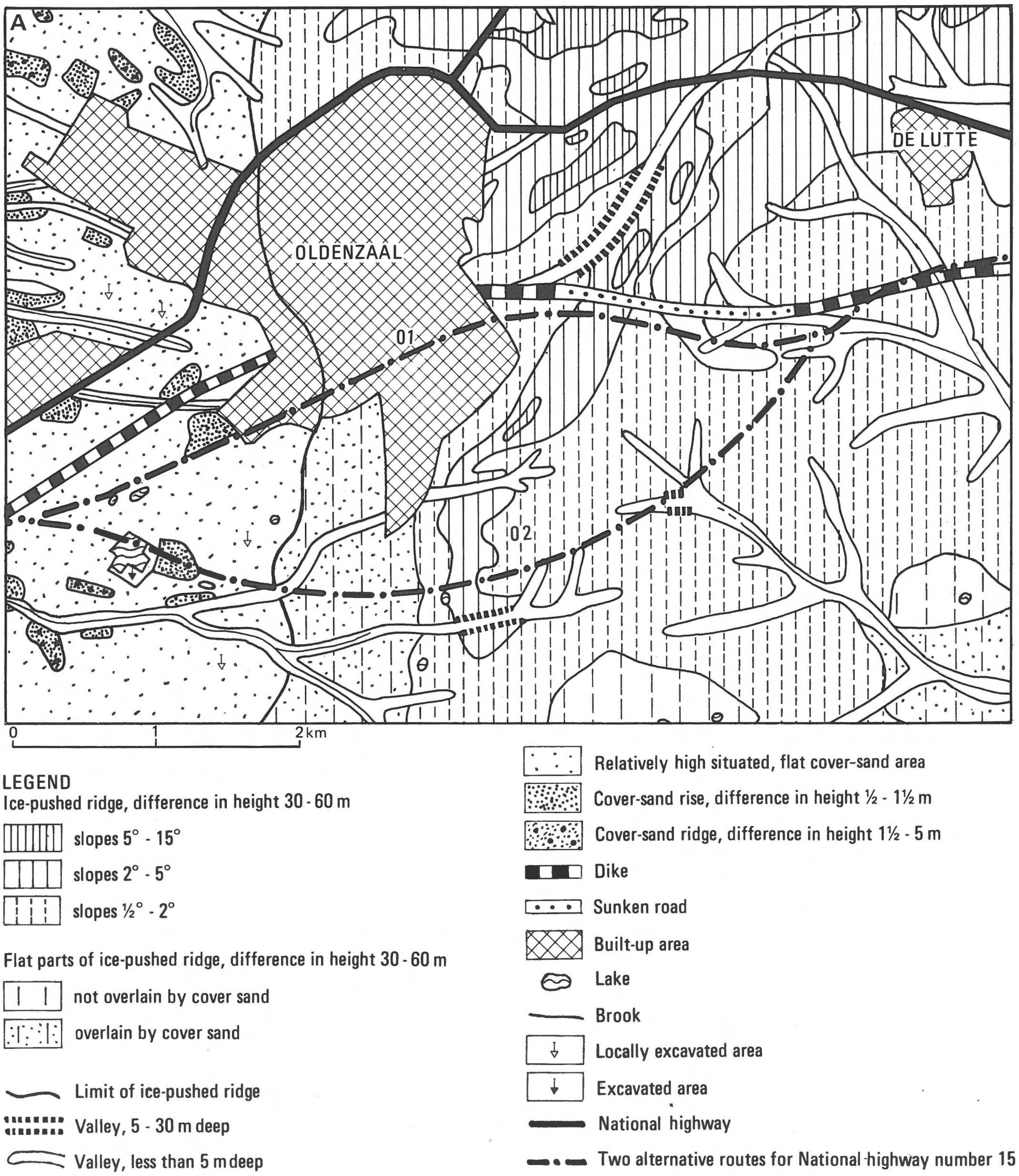


Fig. 7A
Simplified geomorphological map of the surroundings of the town of Oldenzaal.

leys downstream. Around the ice-pushed ridge a zone of relatively high coversand is found. Distinctly visible rises, differing in height from 0.5 to 1.5 m and low ridges differing in height from 1.5 to 5 m have been indicated separately.

When evaluating the geomorphology of this area we must keep in mind that the units mentioned in the legend, and the differences in their heights and steepness of their slopes, are not uncommon in The Netherlands. Exceptions are two valley-systems south of the town of De Lutte where, unlike the dry valley-systems in the central and southern Netherlands, small brooks occur.

The quality and soundness of the units and parts of units distinguished have been determined by evaluating each unit per 0.25 km^2.

Differences in height, steepness of slopes, combinations of different morphological units and the vicinity or presence of built-up areas and other anthropogenic forms were observed. The geomorphological evaluation (Fig. 7b) enables us to see that alternative 01 causes less damage than alternative 02. In the chapter on geomorphology in the report, attention is also paid to possible interception of groundwater when the road is dug in or where passes a valley.

OTHER APPLICATIONS

Soil surveys of reallotment areas are carried out under contract from the Ministry of Agriculture, mainly using a scale of

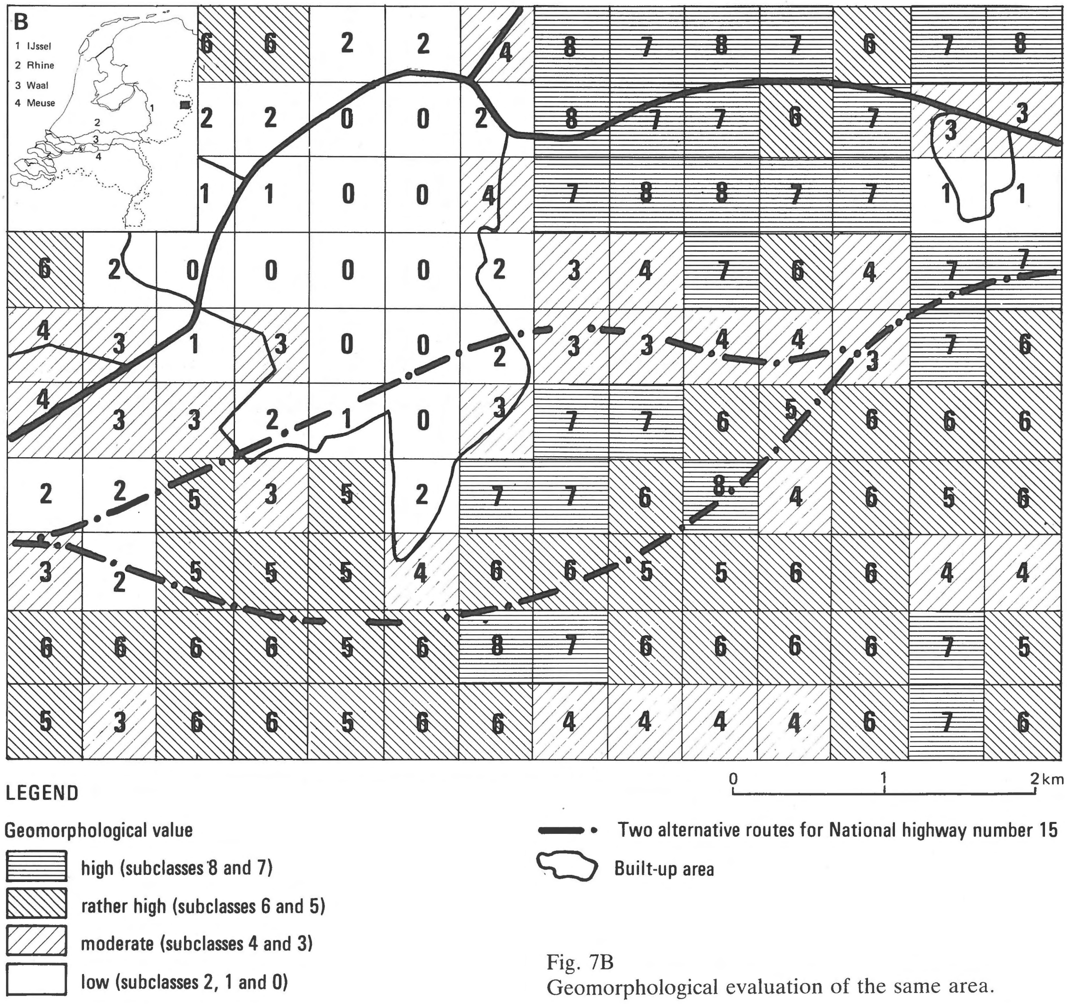


Fig. 7B
Geomorphological evaluation of the same area.

1:25000. In the last few years, geomorphological maps of these areas using a scale of 1:50000 have been requested. These maps are useful because they give an overall view of the terrain configuration and indicate the geomorphologically interesting areas and landforms that should be taken into account when land improvement is carried out. Maps and reports from the following reallotment areas have been published: Waterland-Oost (DE LANGE, 1977), Etten-Leur (DE LANGE, 1978), Over-Betuwe-Oost (DE LANGE, 1979a), Alphen en Riel and Baarle-Nassau (DE LANGE, 1979b), Salland-West (KLEINSMAN & TEN CATE, 1980), Wieringen (TEN CATE, 1980).

Table 3
Functions, aspects and costs of road plans 01 and 02 (after Rijkswaterstaat, 1976)

		Road plan 01	Road plan 02
Functions	residence function	C4	D1
	economic function:		
	industry	C2	A2
	agriculture and forestry	A2	B2
	recreation function	B2	D3
	transport function	A2	C3
Aspects abiotic	geomorphology	B4	D5
	landscape	E3	D4
	cultural history	D2	D1
biotic	botany	D3	D4
	ornithology	D3	D4
Costs (1976)		85 million Dutch guilders	40 million Dutch guilders

Institutes for national and regional planning are displaying increasing interest in geomorphological maps, using them to decide on the most suitable development of a region or area, for instance to indicate sites for urban development and the laying-out of sport fields, in order to preserve rare or interesting geomorphological elements. These maps are also used to indicate areas with possibilities for recreation. Given the flatness of The Netherlands, it is important to know which forms have differences in height of less or more than 1.5 m (which is the eye-height of an observer). Reports, including geomorphological maps, have been published on the following areas: East and South-East Drenthe (TEN CATE & DE LANGE, 1976a), Agglomeration of Eindhoven (TEN CATE & DE LANGE, 1976b), Central Brabant (TEN CATE & DE LANGE, 1977), Twente (TEN CATE, 1979) and Friesland (TEN CATE, 1981).

For road plotting two areas were investigated for terrain forms, deposits and hydrology (MAARLEVELD & DE LANGE, 1973; 1974). Other applications of the geomorphological maps are in landscape physiognomy, in the study of the history of former settlements, in agriculture and in education.

This enumeration shows the interest and potential of geomorphological maps in The Netherlands.

REFERENCES

Berendsen, H. J. A. 1982 De genese van het landschap in het zuiden van de provincie Utrecht, een fysisch-geografische studie (with an English summary) — Utrechtse geogr. stud. 25; Thesis Univ. Utrecht, 259 pp.

Buysrogge, R. A., J. J. Siereveld & J. Visser 1982 Geomorfologische kartering van drooggevallen gebieden in de Grevelingen — Rijkswaterstaat, Deltadienst, Hoofdafd. Milieu en Inrichting, nota DDMI-79.09: 113 pp.

De Lange, G. W. 1977 De geomorfologie van het ruilverkavelingsgebied Waterland-Oost — Stiboka (Wageningen), Rapt. 1302: 17 pp.

—— 1978 De geomorfologie van het ruilverkavelingsgebied Etten-Leur — Stiboka (Wageningen), Rapt. 1364: 20 pp.

—— 1979a De geomorfologie van het ruilverkavelingsgebied Over-Betuwe-Oost — Stiboka (Wageningen), Rapt. 1470: 13 pp.

—— 1979b De geomorfologie van de ruilverkavelingsgebieden Alphen en Riel en Baarle-Nassau — Stiboka (Wageningen), Rapt. 1472: 17 pp.

Demek, J. (ed.): 1972 Manual of detailed geomorphological mapping — Czech. Ac. Sc. Int. Geogr. Un. Comm. Geomorphol. Surv. Map., Academia (Prague): 344 pp.

Demek, J. & C. Embleton (eds): 1976 Guide to medium-scale geomorphological mapping — Int. Geogr. Un. Comm. Geomorphol. Surv. Map., Czechoslovakia, (Brno): 339 pp.

De Soet, F. 1976 De waarden van de uiterwaarden. Een milieukartering en -waardering van de uiterwaarden van IJssel, Rijn, Waal en Maas (with an English summary) — PUDOC, (Wageningen): 89 pp.

Gilewska, S. 1967 Different methods of showing the relief on the detailed geomorphological maps — Z. Geomorphol. (N.F.), 11: 481-490.

Gonggrijp, G. P. 1977 The conservation of important localities of earth science interest in The Netherlands — Information Circular, Nature Conservancy Council, Sect. Geol. Physiogr. 12, 2-6.

Gonggrijp, G. P. & G. J. Boekschoten 1981 Earth-science conservation: No science without conservation — Geol. Mijnbouw, 60: 433-445.

Kleinsman, W. B. & J. A. M. Ten Cate 1980 Geomorfologie van het ruilverkavelingsgebied Salland-West — Stiboka (Wageningen), Rapt. 1476: 29 pp.

Leopold, L. B., F. E. Clarke, B. B. Hanshaw & J. R. Balsley 1971 A procedure for evaluating environmental impact — U.S. Geol. Surv., Circ. 645, (Washington).

Maarleveld, G. C. 1973 Geomorfologische kartering. In: P. D. Jungerius, E. A. Koster & F. J. P. M. Kwaad: Fysische Geografie, aspecten van het landschapsonderzoek — Oosthoek, (Utrecht): 141-150.

—— 1975 Geomorfologische kaart van Nederland, 1:1,200,000. In: Grote Winkler Prins Encyclopedie, 20: 536.

Maarleveld, G. C. & G. W. De Lange 1972 Een globale geomorfologische en landschappelijke kartering en waardering van de uiterwaarden van de Nederlandse grote rivieren (with a summary: Mapping on scale 1:50,000 and evaluation of the geomorphological pattern and of the landscape in the floodplains of the main Dutch rivers) — Landbouwk. Tijdschr., 84: 273-288.

—— 1973 Tracé Rijksweg 50-gedeelte Rijksweg 12-Veluws Eiland. Geomorfologisch Onderzoek — Stiboka, (Wageningen), Rapt. 1108: 14 pp.

—— 1974 Tracé Rijksweg 50-gedeelte Rijksweg 28-Kamperweg. Geomorfologisch Onderzoek — Stiboka, (Wageningen), Rapt. 1168: 12 pp.

—— 1977 Geomorfologie (Bijlage: Geomorfologische kaart van de Veluwe, schaal 1:100,000). In: S. M. Ten Houte de Lange (ed.): Rapport van het Veluwe-onderzoek. Een onderzoek van natuur, landschap en cultuurhistorie ten behoeve van de ruimtelijke ordening en het recreatiegebied — PUDOC, (Wageningen): 15-25, 90 & 105.

Maarleveld, G. C., J. A. M. Ten Cate & G. W. De Lange 1974 Kaartblad III-1 met toelichting (with explanation) Geomorfologie (1:600,000) en kaartblad III-2 met toelichting (with explanation) Geomorfologie: details (1:50,000). In: Atlas van Nederland — Staatsuitgeverij, ('s-Gravenhage).

—— 1975 Legenda geomorfologische kaart van Nederland, schaal 1:50,000 (los blad) — Stiboka (Wageningen); Rijks Geologische Dienst, (Haarlem).

—— 1977 Geomorfologische kaart van Nederland, schaal 1:50,000. Legenda — Stiboka, (Wageningen); Rijks Geologische Dienst, (Haarlem): 20 pp.

Rijkswaterstaat 1976 Rijksweg 15 door of om Oldenzaal, een poging tot analyse en waardering per aspect — Intern rapt Rijkswaterstaat: 25 pp.

Ten Cate, J. A. M. 1969 Valley coversand ridge, a new morphological element in the Guelders Valley — Biul. Periglac. 20: 345-354.

—— 1979 Geomorfologische kartering streekplan Twente — Stiboka, (Wageningen), Rapt. 1406: 26 pp.

—— 1980 De geomorfologie van Wieringen — Stiboka, (Wageningen), Rapt. 1535: 10 pp.

—— 1981 Fysisch-geografische aspecten van het Friesche landschap — Stiboka, (Wageningen), Rapt. 1525: 50 pp.

Ten Cate, J. A. M. & G. W. De Lange 1976a Geomorfologische kartering Oost- en Zuidoost Drenthe, schaal 1:50,000 — Stiboka, (Wageningen), Rapt. 1234: 10 pp.

—— 1976b Agglomeratie Eindhoven Geomorfologie — Stiboka, (Wageningen), Rapt. 1304: 19 pp.

—— 1977 Geomorfologie van Midden-Brabant. Deelrapport 10, Projectstudie Landinrichting Midden-Brabant/Rapport no. 1181 — Stiboka, (Wageningen): 29 pp.

Ten Cate, J. A. M., E. A. Koster, J. J. M. Van der Meer & A. A. De Veer 1981b Maarleveld and his significance to physical geography. A review of the published works of Prof. Dr. G. C. Maarleveld, dedicated to him on his retirement from the University of Amsterdam - K.N.A.G. Geogr. Tijdsch. XV, (5): 377-400.

Ten Cate, J. A. M. & G. C. Maarleveld 1977 Geomorfologische kaart van Nederland, schaal 1:50,000. Toelichting op de legenda — Stiboka, (Wageningen); Rijks Geologische Dienst, (Haarlem): 91 pp.

Ten Cate, J. A. M., M. F. Van Oosten & M. W. Ter Wee 1981a Vergelijking van de nieuwe geologische kaart, de geomorfologische kaart en de bodemkaart, schaal 1:50,000, toegelicht met een fragment van blad 17 Oost — K.N.A.G. Geogr. Tijdschr. XV, (1): 35-55.

Ten Houte de Lange, S. M. 1977 Rapport van het Veluwe-onderzoek. Een onderzoek van natuur, landschap en cultuurhistorie ten behoeve van de ruimtelijke ordening en het recreatiebeleid — PUDOC, (Wageningen): 263 pp.

Van Dorsser, H. J. & A. J. Salomé 1973 Different methods of detailed geomorphological mapping — K.N.A.G. Geogr. Tijdschr. N.R., 7: 71-74.

Wijnhoven, A. L. J., M. J. S. M. Reijnen & J. H. Smittenberg 1979 Het Noorden Natuurlijk. Samenvattend rapport van het milieuonderzoek voor het Integraal Structuurplan Noorden des Lands — Staatsuitgeverij, ('s-Gravenhage): 140 pp.