VENEZUELA

Source: esri

General

Venezuela - officially the Bolivarian Republic of Venezuela - is a federal republic on the northern coast of South America, bordered by Colombia in the West, Brazil in the South, Guyana in the East, the Dutch Lesser Antilles in the North and Trinidad and Tobago in the North-east. Venezuela has an area of 91.6 Mha (million hectares) with, in 2022 a population of 28.3 million, or 0.31 persons per ha (Wikipedia and United Nations, 2022).

Climate and geography

Venezuela is entirely located in the tropics over the Equator to around 12° North. Its climate varies from humid in the low-elevation plains, where average annual temperatures range as high as 35 °C, to glaciers and highlands with an average annual temperature of 8 °C. Annual rainfall varies from 430 mm in the semi-arid portions of the Northwest to over 1,000 mm in the Orinoco Delta of the far East and the Amazonian Jungle in the South. The precipitation level is lower in the period from November to April and later in the year from August to October. These periods are referred to as hot-humid and cold-dry seasons. Another characteristic of the climate is this variation throughout the country by the existence of a mountain range called *Cordillera de la Costa*, which crosses the country from East to West. The majority of the population lives in these mountains. The country falls into four horizontal temperature zones based primarily on elevation, having tropical, dry, temperate with dry winters, and polar climates, amongst others. In the tropical zone - below 800 m temperatures are hot, with annual averages ranging between 26 and 28 °C (source: Wikipedia).

Rostain (2010) describes that causeways were frequent in Arauquinoid sites of the Llanos de Apure in Venezuela (Redmond and Spencer, 2007).

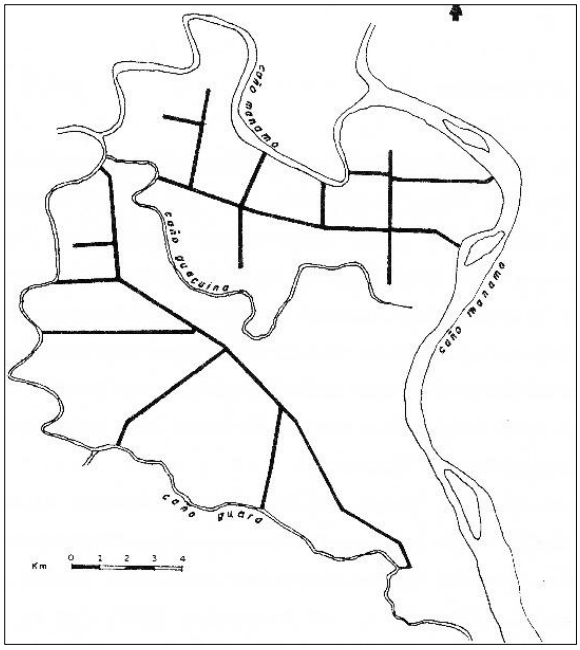
Venezuela is one of the most important oil-producing countries in the World. Before 1975 most of the oil was extracted from the east coast of Lake of Maracaibo and from wells in the lake (Zulia State). At present that situation has changed from 90 to 45% nowadays. The oil is between 300 and 1000 m deep and is extracted both in the lake and on land in extraction wells in a grid of approximately 250 * 250 m. Because of the shallow extraction there is a significant land subsidence. In the final stage of oil extraction this subsidence may be up to about 10 m in the most affected areas. When oil extraction started in 1926, the ground level was at about 2 m+MSL (mean sea level). The Bolivar Coast region on the east coast of Lake Maracaibo has an area of about 230,000 hectares. The oil extraction started in the Lagunillas area and has gradually spread over the area. The subsidence is more or less directly linked to the oil extraction. When the oil production will be completed around 2025, the ground level in the deepest places will therefore be about 8 m-MSL. In 2017 the ground level in Lagunillas Polder was at about 7 m-MSL (Schultz and Mendez, submitted).

A complication is that the area may be subject to earthquakes. Because of this in line with the development of the extraction of the oil, measures in the field of flood protection and water management were implemented, operated and maintained. The former state oil company Maraven was responsible for all these measures, but now the state oil company Petroleos de Venezuela S.A. (PDVSA) is responsible for them. This is quite different from the general approach, where most responsibility generally rests with government water management agencies.

Existing polders

Four polders - Tia Juana, Lagunillas, Pueblo Viejo and Bachaquero - have been developed along the coast, each having roughly the shape of a semi-circle with the coast as a straight line. In total they cover almost 20,000 hectares (Abi-Saab Soto *et al*,. 1983).

Sallaber (1983) mentions that in the Orinoco Delta successfully open polders (horse shoe shape) have been implemented (Figure 1).



Figuur 1. Two polders on the Guara Island in the Orinoco Delta (Yanes and Acevedo, 1983)

Yanes and Acevedo (1983) describe two polders on the Guara Island in the Orinoco Delta.

General characteristics of the polders in Venezuela are shown in Table I. Table II shows the characteristics of the water management and flood protection systems of the existing polders.

Proposed polders

No proposed polders have been identified.

Water management and flood protection systems

For the Bolivar Coast Polders with the very high investments in the oil extraction and related urban and industrial facilities flood protection at a high level of safety is crucial. However, the dikes run through the heart of the oil fields. Harbours and power stations have been built in, or near the dikes, many pipelines for oil transport, steam- and water supply are crossing the dikes and oil wells are located on the dikes and in their direct vicinity. As long as the difference between the water level in the lake and the water level in the drains was not too large this was not a major problem. However, when the subsidence progressed, increasingly inspection of the dikes was required and measures to heighten and strengthen them had to be taken. Some of these measures were (Abi-Saab Soto *et al*,. 1983):

- all pipes crossing the dikes have been raised above the crest of the dike to create a free crossing;
- precautionary measures have been taken at the oil wells on, or near the vicinity of the dikes, which made it in principle impossible that gas can escape to the surface from leaking casings, while such escapes could lead to instability of the dike body.

The flood protection refers to protection from the lake as well as to protection from flooding by the rivers that cross the area on their way from the Andes Mountains to the lake. In total about 42 kilometres coastal dikes and 58 kilometres interior or diversion dikes have been built, creating the four Bolivar Coast Polders. Outside the diversion dikes collector drains have been built to collect and convey the river water to the lake. Within the polders, basically in a logical grid related to the road system. a system of primary and secondary drains has been developed to store the excess rainwater in the polders and convey it to the drainage pumping stations. This system would in principle have to store and discharge the excess water of rainstorms based on a chance of occurrence of once in ten years, based on available data of 83 millimetres in one hour for Lagunillas Polder and 110 millimetres in one hour for Bachaquero Polder. Some specifications of the drainage pumping stations are shown in Table II. Due to the ongoing and locally different subsidence the dikes and drains have to be adapted from time to time.

The dikes also have to be heightened and strengthened, while the protected areas became lower and lower over time. However, during the last 15 years those works have considerably been reduced and there is a need for evaluating and maintaining those works.

Figure 2. Electric drainage pumping station and the dike of Polder Lagunillas, one of the Bolivar Coast Polders

Location of the polders in Venezuela as shown on the World polder map

The locations of the polders in Venezuela are shown in Figure 3.

Figure 3. Location of the polders in Venezuela (source: esri – Batavialand)

Table III shows the pictures by Prof. Adriaan Volker. Table IV shows the pictures by Prof. Bart Schultz.

References

Abi-Saab Soto, J., W.J. Heijnen, P.W. Roest and H. Velsink, 1983. *Polders and dykes of the Bolivar Coast, Venezuela*. In: Proceedings International Symposium 'Polders of the World'. International Institute for Land Reclamation and Improvement, Wageningen, the Netherlands.

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Yanes, A. and M.F. Acevedo, 1983. *Tide-driven drainage networks: the case of Guara Island.* In: Proceedings International Symposium 'Polders of the World'. International Institute for Land Reclamation and Improvement, Wageningen, the Netherlands.

Bart Schultz

Lelystad, June 2023

Table I. General characteristics of existing polders in Venezuela

Name	Reclamation	Area in ha	Type *)	Latitudes	Longitudes	Elevation in M+MSL	Land use
Tia Juana		2,200	RLL	10º 16' N	71º 22' W	-5	Oil extraction
Lagunillas		9,325	RLL	10º 08' N	71º 14' W	-7	Oil extraction
Pueblo Viejo		920	RLL	9º 59' N	71º 12' W	0	Oil extraction
Bachaquero		6,315	RLL	9º 58' N	71º 08' W	-5	Oil extraction
Open polders in the Orinoco Delta			RLL				Agriculture
Two polders at Guara Island			RLL	9º 01' N	62º 08' W	3	Agriculture
Total		18,760					

*) RLL = reclaimed low-lying land; LGS = land gained on the sea; DL = drained lake

Table II. Characteristics of the water management and flood protection system of existing polders in Venezuela

Name	Design criteria in chance of occurrence/year							
	Water management						Flood protection	
	Drainage					Irrigation	Rural	Urban
	Type	Design criterion	Percentage of open water	Discharge capacity m^3/s	Discharge capacity mm/day			
Tia Juana	RLL	10% per year		21.1	83.0			
Lagunillas	RLL	10% per year		15.1	14.9			
Pueblo Viejo	RLL	10% per year		3.6	16.8			
Bachaquero	RLL	10% per year		8.8	12.0			
Open polders in the Orinoco Delta	RLL							
Two polders at Guara Island	RLL							

Table III. Pictures by Prof. Adriaan Volker on polders in Venezuela

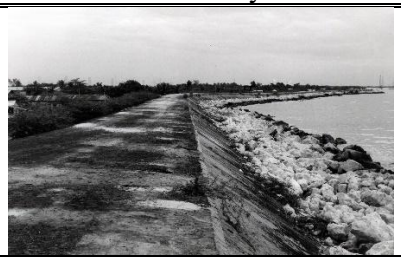
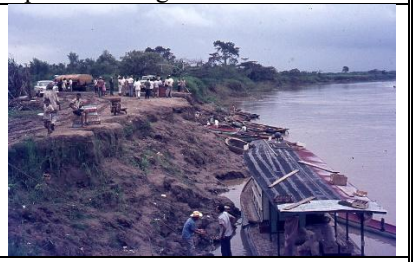
			
A3 001/V.3.1 Oil extraction in Lake of Maracaibo	A3 002/V.3.2 Dike of one of the Bolivar Coast polders along Lake of Maracaibo	A3 003/V.3.3 Dike of one of the Bolivar Coast polders along Lake of Maracaibo	A4 1 001/A.4.1.1 Dike of one of the Bolivar Coast polders along Lake of Maracaibo
			
A4 1 002/A.4.1.2 Dike of one of the Bolivar Coast polders along Lake of Maracaibo	A4 1 003/A.4.1.3 Oil extraction in Lake of Maracaibo	A4 1 004/A.4.1.4 Oil extraction in Lake of Maracaibo	A4 1 005/A.4.1.5 One of the Bolivar Coast polders along Lake of Maracaibo

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela

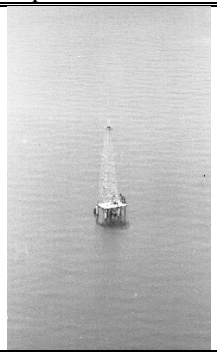
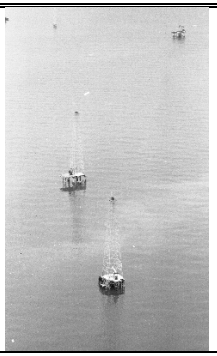
			
Row 1 001/III/1-1 One of the Bolivar Coast Polders with in the background Lake of Maracaibo, May 1982	Row 2 001/III/2-1 One of the Bolivar Coast Polders with in the background Lake of Maracaibo, May 1982	Row 2 002/III/2-2 Drilling rig for oil extraction in Lake of Maracaibo, May 1982	Row 2 003/III/2-3 Drilling rig for oil extraction in Lake of Maracaibo, May 1982
			
Row 2 004/III/2-4 Drainage pumping station of Polder Tia Juana, one of the Bolivar Coast Polders, that discharges at Lake of Maracaibo,May 1982	Row 3 001/III/3-1 Dike section of the polder Tia Juana, one of the Bolivar Coast Polders, along the Lake of Maracaibo, May 1982	Row 3 002/III/3-2 Nodding donkey in the dike of the Polder Tia Juana, one of the Bolivar Coast Polders, along Lake of Maracaibo, May 1982	Row 3 003/III/3-3 Nodding donkey in the dike of the polder Tia Juana, one of the Bolivar Coast Polders, along Lake of Maracaibo, May 1982

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela (continued)

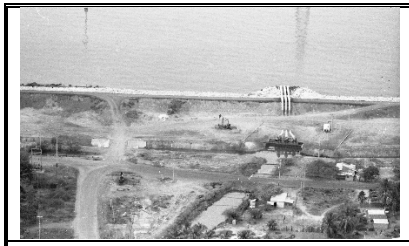
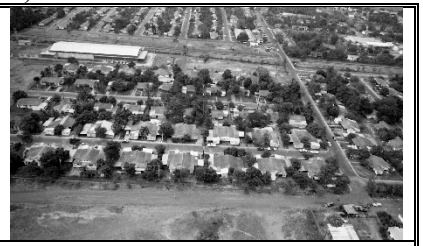
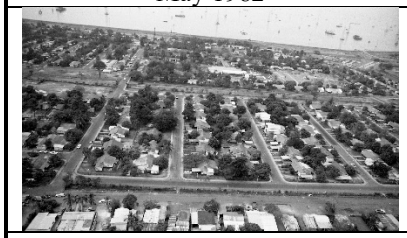
			
Row 3 004/III/3-4 Drainage pumping station of Polder Lagunillas, one of the Bolivar Coast Polders, that discharges at Lake of Maracaibo, May 1982	Row 4 001/III/4-1 Nodding donkeys in the dike of the polder Lagunillas, one of the Bolivar Coast Polders, along Lake of Maracaibo, May 1982	Row 4 002/III/4-2 Urban quarter and factory hall of the Village Lagunillas with at the background the dike of the Polder Lagunillas and drilling rigs in Lake of Maracaibo, May 1982	Row 4 003/III/4-3 Urban quarter and factory hall of the Village Lagunillas, May 1982
			
Row 4 004/III/4-4 Urban quarter and factory hall of the Village Lagunillas with at the background the dike of the Polder Lagunillas and drilling rigs in Lake of Maracaibo, May 1982	Row 5 001/III/5-1 Urban quarter and factory hall of the Village Lagunillas with at the background the dike of the Polder Lagunillas and drilling rigs in Lake of Maracaibo, May 1982	Row 5 002/III/5-2 Urban quarter and factory hall of the Village Lagunillas with at the background the dike of the Polder Lagunillas and drilling rigs in Lake of Maracaibo, May 1982	Row 5 003/III/5-3 Factory halls and oil tanks with at the background the dike of the Polder Lagunillas and drilling rigs in Lake of Maracaibo, May 1982

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela (continued)

			
Row 5 004/III/5-4 Oil tanks of the Village Lagunillas with at the background the dike of the Polder Lagunillas and drilling rigs in Lake of Maracaibo, May 1982	Row 6 001/III/6-1 Oil tanks of the Village Lagunillas with at the background the dike of the Polder Lagunillas and drilling rigs in Lake of Maracaibo, May 1982	D1 2 026/II-26 Dike of and nodding donkey for oil extraction in Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 027/II-27 Dike of and nodding donkey for oil extraction in Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982
			
D1 2 028/II-28 Dike and nodding donkey for oil extraction in Polder Lagunillas, one of the Bolivar Coast Polders. In addition drilling rigs for oil extraction in Lake of Maracaibo, 17-22 May 1982	D1 2 029/II-29 Dike of Polder Lagunillas, one of the Bolivar Coast Polders. In addition drilling rigs for oil extraction in Lake of Maracaibo, 17-22 May 1982	D1 2 030/II-30 Drilling rigs for oil extraction in Lake of Maracaibo, 17-22 May 1982	D1 2 031/II-31 Rip rap at the outer slope of the dike of one of the Bolivar Coast Polders. In addition drilling rigs for oil extraction in Lake of Maracaibo, 17-22 May 1982

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela (continued)

			
D1 2 032/II-32 Discharge pipe of one of the drainage pumping stations for one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 033/II-33 Drilling rigs for oil extraction in Lake of Maracaibo, 17-22 May 1982	D1 2 034/II-34 Discharge pipe of one of the drainage pumping stations for one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 035/II-35 Nodding donkey for oil extraction in the dike of Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982
			
D1 2 036/II-36 Electric drainage pumping station and the dike of Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 037/II-37 Oil pipes through a culvert in one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 038/II-38 Oil pipes through a culvert in one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 039/II-39 Salinization due to oil extraction in one of the Bolivar Coast Polders, 17-22 May 1982

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela (continued)

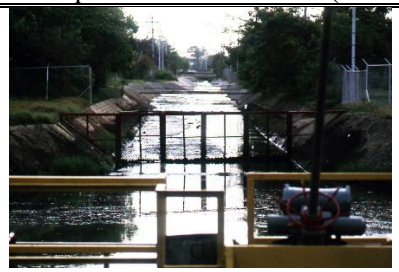
			
D1 2 040/II-40 Salinization due to oil extraction in one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 041/II-41 Oil pollution in one of the drains in Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 042/II-42 Oil pollution in one of the drains in Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 043/II-43 Discharge point for excess rainfall of a road in Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982
			
D1 2 044/II-44 Outlet of a discharge point for excess rainfall of a road in a drain in Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 045/II-45 Drain for the discharge of excess rainfall of a road in Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 046/II-46 Drain for the discharge of excess rainfall of a road in Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982	D1 2 047/II-47 Discharge point for excess rainfall from a road in Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela (continued)

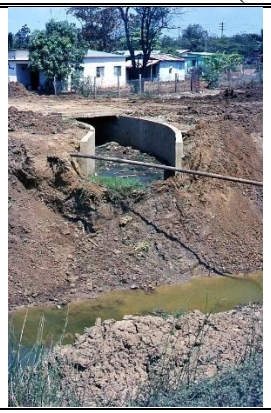
			
D1 2 048/II-48 Main drain for the discharge of excess rainfall from roads in Polder Lagunillas, one of the Bolivar Coast Polder, 17-22 May 1982	D1 2 049/II-49 Nodding donkey for oil extraction in Polder Lagunillas, one of the Bolivar Coast Polders, 17-22 May 1982	HD 18 022/XVIII-22 Rainwater discharge point in one of the Bolivar Coast Polders	HD 18 023/XVIII-23 Aerial picture of one of the Bolivar Coast Polders
			
HD 18 024/XVIII-24 Aerial picture of one of the Bolivar Coast Polders	HD 18 025/XVIII-25 Aerial picture of one of the Bolivar Coast Polders	HD 18 026/XVIII-26 Dike slope of one of the inland dikes of one of the Bolivar Coast Polders	HD 18 027/XVIII-27 Aerial picture of one of the Bolivar Coast Polders

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela (continued)

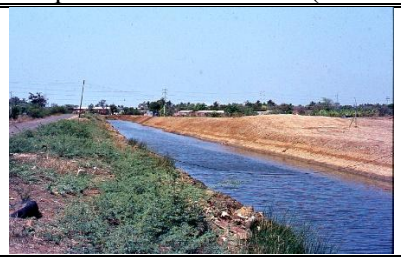
			
HD 18 028/XVIII-28 Aerial picture of one of the Bolivar Coast Polders	HD 18 029/XVIII-29 Aerial picture of one of the Bolivar Coast Polders	HD 18 030/XVIII-30 Canal in the Polder Tia Juana, one of the Bolivar Coast Polders	HD 18 031/XVIII-31 Aerial picture of an electrical drainage pumping station for one of the Bolivar Coast Polders that discharges to Lake of Maracaibo
			
HD 18 032/XVIII-32 Deforestation for oil extraction in one of the Bolivar Coast Polders	HD 18 033/XVIII-33 Inland dike of one of the Bolivar Coast Polders	HD 18 034/XVIII-34 Aerial picture of one of the drainage pumping stations for the polder Bachequero, one of the Bolivar Coast Polders, that discharges at Lake of Maracaibo	HD 18 035/XVIII-35 Inland dike of one of the Bolivar Coast Polders

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela (continued)

			
HD 18 036/XVIII-36 Inland dike of one of the Bolivar Coast Polders	HD 18 037/XVIII-37 Aerial picture of one of the Bolivar Coast Polders	HD 18 038/XVIII-38 Aerial picture of oil extraction installations (nodding donkeys) in one of the Bolivar Coast Polders	HD 18 039/XVIII-39 Deforestation along an inland dike because of oil extraction in one of the Bolivar Coast Polders
			
HD 18 040/XVIII-40 Aerial picture Bolivar Coast Polders	HD 18 041/XVIII-41 Aerial picture Bolivar Coast Polders	HD 18 042/XVIII-42 Aerial picture Bolivar Coast Polders	HD 18 043/XVIII-43 Aerial picture Bolivar Coast Polders

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela (continued)

			
HD 18 044 XVIII-44/Dike and coastal area of one of the Bolivar Coast Polders along Lake of Maracaibo. In addition drilling rigs for oil extraction in Lake of Maracaibo	HD 18 045/XVIII-45 Dike and coastal area of one of the Bolivar Coast Polders along Lake of Maracaibo. In addition drilling rigs for oil extraction in Lake of Maracaibo	HD 18 046/XVIII-46 Aerial picture of an installation for oil extraction (nodding donkey) and degassing installation in the inner slope of the dike of one of the Bolivar Coast Polders	HD 18 047/XVIII-47 Aerial picture of an installation for oil extraction (nodding donkey) and degassing installation in the inner slope of the dike of one of the Bolivar Coast Polders
			
HD 18 048/XVIII-48 Aerial picture of an installation for oil extraction (nodding donkey) in the inner slope of the dike of one of the Bolivar Coast Polders	HD 18 049/XVIII-49 Aerial picture of an harbour area in one of the Bolivar Coast Polders	HD 18 050/XVIII-50 Oil pollution in a harbor of one of the Bolivar Coast Polders	HD 19 001/XIX-1 Aerial picture of the coastal area of one of the Bolivar Coast Polders and Lake of Maracaibo with drilling rigs for oil extraction

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela (continued)

			
HD 19 002/XIX-2 Aerial picture of the coastal area of one of the Bolivar Coast Polders and Lake of Maracaibo with drilling rigs for oil extraction	HD 19 003/XIX-3 Inner slope of the dike of one of the Bolivar Coast Polders along Lake of Maracaibo with in front one of the main drains of the polder	HD 19 004/XIX-4 Dike of one of the Bolivar Coast Polders along Lake of Maracaibo with aside one of the main drains of the polder	HD 19 005/XIX-5 Provision for storage of oil pollution in one of the Bolivar Coast Polders
			
HD 19 006/XIX-6 Aerial picture of the coastal area of one of the Bolivar Coast Polders and Lake of Maracaibo with drilling rigs for oil extraction	HD 19 007/XIX-7 Aerial picture of the coastal area of one of the Bolivar Coast Polders	HD 19 008/XIX-8 Aerial picture of one of the Bolivar Coast Polders with in the background Lake of Maracaibo	HD 19 009/XIX-9 Aerial picture of a collector tank for oil pollution in one of the Bolivar Coast Polders

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela (continued)

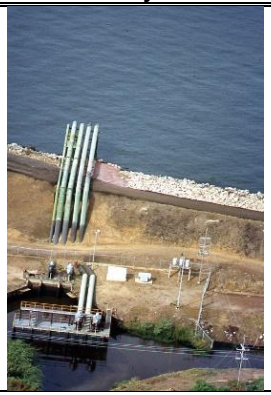
			
HD 19 010/XIX-10 Oil pipelines in one of the Bolivar Coast Polders	HD 19 011/XIX-11 Aerial picture of a drainage pumping station for one of the Bolivar Coast Polders	HD 19 012/XIX-12 Canal in one of the Bolivar Coast Polders	HD 19 013/XIX-13 Canal, bridge and bank protection in one of the Bolivar Coast Polders
			
HD 19 014/XIX-14 Collector point and storage tank for oil pollution in one of the Bolivar Coast Polders	HD 19 015/XIX-15 Inland dike of one of the Bolivar Coast Polders	HD 19 016/XIX-16 River that flow between two Bolivar Coast Polders and drains in Lake of Maracaibo	HD 19 017/XIX-17 River that flow between two Bolivar Coast Polders and drains in Lake of Maracaibo

Table IV. Pictures by Prof. Bart Schultz on polders in Venezuela (continued)

			
HD 19 018/XIX-18 Discharge pipe of a drainage pumping station for one of the Bolivar Coast Polders near Lake of Maracaibo	HD 19 019/XIX-19 Discharge pipe of a drainage pumping station for one of the Bolivar Coast Polders near Lake of Maracaibo	HD 19 020/XIX-20 Discharge pipe of a drainage pumping station for one of the Bolivar Coast Polders near Lake of Maracaibo	HD 19 021/XIX-21 Discharge pipe of a drainage pumping station for one of the Bolivar Coast Polders near Lake of Maracaibo. Close behind dike also a nodding donkey for oil extraction
			
HD 19 022/XIX-22 Culverts under a raod at the crossing of one of the drains in one of the Bolivar Coast Polders	HD 19 023/XIX-23 One of the drainage pumping stations of Polder Lagunillas, one of the Bolivar Coast Polders, with a provision for the collection of oil pollution	D8 25 028/XXV-28 Oil extraction in one of the Bolivar Coast Polders	