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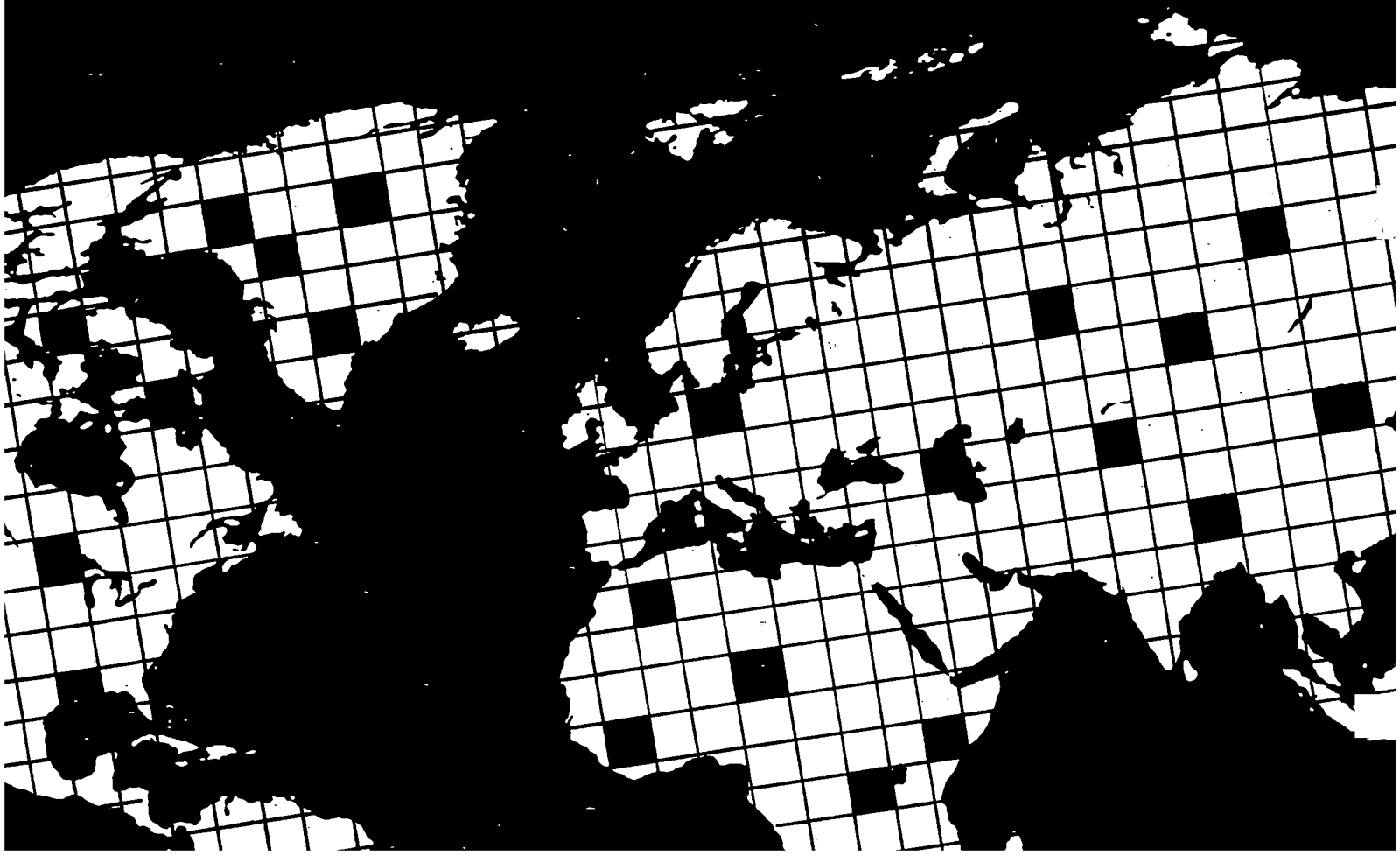
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United States Department of State

Principal Officers of the Department of State and United States Chiefs of Mission

1778 - 1988



Finland (*Continued*)

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
Jack K. McFall	D.C.	C	EE/MP	10 Sept. 1952[r] 1 May 1953	15 Nov. 1952	Recommissioned after confirmation Promoted to AE/P
			AE/P	15 Sept. 1954[r] 3 Dec. 1954	17 Sept. 1954[4]	Recommissioned after confirmation Left post, 19 Sept. 1955
John D. Hickerson	Tex.	C	AE/P	4 Oct. 1955[r] 25 Jan. 1956	23 Nov. 1955	Recommissioned after confirmation Left post, 3 Nov. 1959
Edson O. Sessions	Ill.	NC	AE/P	20 Oct. 1959[r] 21 Jan. 1960	28 Nov. 1959	Recommissioned after confirmation Left post, 20 Nov. 1960
Bernard Gufler	Wash.	C	AE/P	24 Feb. 1961	14 Apr. 1961	Left post, 18 Apr. 1963
Carl T. Rowan	Minn.	NC	AE/P	9 Mar. 1963	21 May 1963	Left post, 8 Feb. 1964
Tyler Thompson	Me.	C	AE/P	31 July 1964	25 Aug. 1964	Left post, 14 June 1969
Val Peterson	Nebr.	NC	AE/P	1 May 1969	14 July 1969	Left post, 23 Mar. 1973
V. John Krehbiel	Cal.	NC	AE/P	27 Mar. 1973	1 June 1973	Left post, 24 Feb. 1975
Mark Evans Austad	Utah	NC	AE/P	20 Feb. 1975	20 Mar. 1975	Left post, 14 Apr. 1977
Rozanne L. Ridgway	D.C.	C	AE/P	26 May 1977	5 Aug. 1977	Left post, 20 Feb. 1980
James Eugene Goodby	N.H.	C	AE/P	27 Feb. 1980	11 Apr. 1980	Left post, 18 Aug. 1981
Keith Foote Nyborg	Id.	NC	AE/P	30 July 1981	18 Sept. 1981	Left post, 17 Feb. 1986
Rockwell Anthony Schnabel	Cal.	NC	AE/P	17 Dec. 1985	28 Feb. 1986	

[4]Legation Helsinki was raised to Embassy status on 10 Sept. 1954.

France

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
Benjamin Franklin[1]	Pa.		MP	14 Sept. 1778	23 Mar. 1779	Superseded, 17 May 1785
Thomas Jefferson	Va.		MP	10 Mar. 1785 12 Oct. 1787	17 May 1785	Recommissioned Left post, 26 Sept. 1789
William Short	Va.		CdA	20 Apr. 1790	14 June 1790	Presented recall, 15 May 1792
Gouverneur Morris	N.Y.		MP	12 Jan. 1792	3 June 1792	Recall requested by Govt. of France, 9 Apr. 1794[2]
James Monroe	Va.		MP	28 May 1794	15 Aug. 1794	Presented recall, 9 Dec. 1796
Charles Cotesworth Pinckney[3]	S.C.		MP	9 Sept. 1796[r]		
William Vans Murray[4]			MP			
James A. Bayard[5]	Del.		MP	19 Feb. 1801		
Robert R. Livingston	N.Y.		MP	2 Oct. 1801	6 Dec. 1801	Presented recall, 18 Nov. 1804
John Armstrong[6]	N.Y.		MP	30 June 1804[r]	18 Nov. 1804	Left post, 14 Sept. 1810
Jonathan Russell	R.I.		CdA	[5 Nov. 1810[7]]	[8]	Superseded, 17 Nov. 1811
Joel Barlow	D.C.		MP	27 Feb. 1811	17 Nov. 1811	Died at Zarnowiec, 26 Dec. 1812, en route to Paris from consultations with French officials in Russia
William H. Crawford	Ga.		MP	9 Apr. 1813[r] 28 May 1813	14 Dec. 1813	Recommissioned after confirmation Reaccredited when France again became a kingdom.
					16 Aug. 1814	Left post, 26-30 Apr. 1815
Albert Gallatin	Pa.		EE/MP	28 Feb. 1815	16 July 1816	Left post, 16 May 1823
James Brown	La.		EE/MP	9 Dec. 1823	13 Apr. 1824	Had farewell audience, 28 June 1829
William C. Rives	Va.		EE/MP	18 Apr. 1829[r] 10 Feb. 1830	25 Oct. 1829	Recommissioned after confirmation Reaccredited after change of government
					[14 Jan. 1831[9]]	Left post, 27 Sept. 1832
Levett Harris	N.J.		CdA	6 Mar. 1833	20 Apr. 1833	Superseded, 30 Sept. 1833

[1]Commissioned also to negotiate a treaty with Sweden.

[2]Morris was still at his post when his successor presented credentials.

[3]Proceeded to post, but was not received by the Directory; left post, 5 Feb. 1797. Nomination was confirmed by the Senate, but no record has been found of a new commission following confirmation.

[4]Not commissioned; nomination superseded by a nomination of Murray and two others to serve on a joint commission.

[5]Did not serve under this appointment.

[6]Nomination was confirmed by the Senate, but no record has been found of a new commission following confirmation.

[7]Commission not of record, but enclosed with an instruction of this date.

[8]Received his commission about 13 Feb. 1811; was not issued a letter of credence, but continued his official relations with the Govt. of France begun in Sept. 1810 as Chargé d'Affaires ad interim.

[9]Formally received on this date.

France (*Continued*)

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
Edward Livingston			EE/MP	29 May 1833[r] 5 Mar. 1834	30 Sept. 1833	Recommissioned after confirmation Left post, 29 Apr. 1835[10]
Lewis Cass			EE/MP	4 Oct. 1836	1 Dec. 1836	Left post, 12 Nov. 1842
Henry A. Wise[11]	Va.		EE/MP			
William R. King	Ala.		EE/MP	9 Apr. 1844	1 July 1844	Presented recall, 15 Sept. 1846
Charles J. Ingersoll[12]	Pa.		EE/MP			
Richard Rush	Pa.		EE/MP	3 Mar. 1847	31 July 1847	Reaccredited when France again became a republic
					26 Apr. 1848	Presented recall, 8 Oct. 1849
William C. Rives	Va.		EE/MP	20 July 1849[r] 18 Mar. 1850	8 Nov. 1849	Recommissioned after confirmation Reaccredited when France again became an empire
					10 Jan. 1853	Presented recall, 12 May 1853
John Y. Mason	Va.		EE/MP	10 Oct. 1853[r] 6 Dec. 1853	22 Jan. 1854	Recommissioned after confirmation Died at post, 3 Oct. 1859
Charles J. Faulkner	Va.		EE/MP	16 Jan. 1860	4 Mar. 1860	Presented recall, 12 May 1861
William L. Dayton	N.J.		EE/MP	18 Mar. 1861	19 May 1861	Died at post, 1 Dec. 1864
John Bigelow	N.Y.		EE/MP	15 Mar. 1865[r] 22 Jan. 1866	23 Apr. 1865	Recommissioned after confirmation Presented recall, 23 Dec. 1866
John A. Dix	N.Y.		EE/MP	24 Sept. 1866[r] 2 Mar. 1867	23 Dec. 1866	Recommissioned after confirmation Presented recall, 23 May 1869
Elihu B. Washburne	Ill.		EE/MP	17 Mar. 1869	23 Mar. 1869	Reaccredited when France again became a republic
					8 May 1871	Presented recall, 5 Sept. 1877
Edward F. Noyes	O.		EE/MP	1 July 1877[r] 30 Oct. 1877	5 Sept. 1877	Recommissioned after confirmation Presented recall, 5 Aug. 1881
Levi P. Morton	N.Y.		EE/MP	21 Mar. 1881	5 Aug. 1881	Presented recall, 14 May 1885
Robert M. McLane	Md.		EE/MP	23 Mar. 1885	14 May 1885	Presented recall, 20 May 1889
Whitelaw Reid	N.Y.		EE/MP	23 Mar. 1889	21 May 1889	Left post, 25 Mar. 1892
T. Jefferson Coolidge	Mass.		EE/MP	12 May 1892	10 June 1892	Presented recall, 4 May 1893
James B. Eustis	La.		EE/MP AE/P	20 Mar. 1893[13] 8 Apr. 1893	6 May 1893	Presented recall, 24 May 1897
Horace Porter	N.Y.		AE/P	19 Mar. 1897	26 May 1897	Presented recall, 2 May 1905
Robert S. McCormick	Ill.		AE/P	8 Mar. 1905	2 May 1905	Presented recall, 2 Mar. 1907
Henry White	R.I.		AE/P	19 Dec. 1906	23 Mar. 1907	Left France, 3 Nov. 1909
Robert Bacon	N.Y.		AE/P	21 Dec. 1909	31 Dec. 1909	Presented recall, 19 Apr. 1912
Myron T. Herrick	O.		AE/P	15 Feb. 1912	29 Apr. 1912	Left post, 28 Nov. 1914
William G. Sharp	O.	NC	AE/P	19 June 1914	4 Dec. 1914	Presented recall, 14 Apr. 1919
Hugh Campbell Wallace	Wash.	NC	AE/P	27 Feb. 1919	22 Apr. 1919	Presented recall, 5 July 1921
Myron T. Herrick	O.	NC	AE/P	16 Apr. 1921	15 July 1921	Died at post, 31 Mar. 1929
Walter E. Edge	N.J.	NC	AE/P	21 Nov. 1929	18 Dec. 1929	Presented recall, 13 Apr. 1933
Jesse Isidor Straus	N.Y.	NC	AE/P	17 Mar. 1933	8 June 1933	Left France, 5 Aug. 1936
William Christian Bullitt	Pa.	NC	AE/P	25 Aug. 1936[r] 23 Jan. 1937	13 Oct. 1936	Recommissioned after confirmation Left La Bourboule, 11 July 1940[14]
William D. Leahy	Ga.	NC	AE/P	29 Nov. 1940	8 Jan. 1941	Left Vichy, 1 May 1942[15]
Jefferson Caffery	La.	C	AE/P	25 Nov. 1944	30 Dec. 1944[16]	Left post, 13 May 1949
David K. E. Bruce	Va.	NC	AE/P	9 May 1949	17 May 1949	Left post, 10 Mar. 1952
James Clement Dunn	N.Y.	C	AE/P	13 Mar. 1952	27 Mar. 1952	Left post, 2 Mar. 1953
C. Douglas Dillon	N.J.	NC	AE/P	27 Feb. 1953	13 Mar. 1953	Left post, 28 Jan. 1957
Amory Houghton	N.Y.	NC	AE/P	14 Mar. 1957	17 Apr. 1957	Left post, 19 Jan. 1961
James M. Gavin	Mass.	NC	AE/P	22 Feb. 1961	21 Mar. 1961	Left post, 26 Sept. 1962
Charles E. Bohlen	D.C.	C	AE/P	4 Sept. 1962	27 Oct. 1962	Left post, 9 Feb. 1968
Robert Sargent Shriver, Jr.	Ill.	NC	AE/P	22 Apr. 1968	25 May 1968	Left post, 25 Mar. 1970

[10]Thomas P. Barton served as Chargé d'Affaires ad interim until 8 Nov. 1835, when he closed Legation Paris, having been recalled.

[11]Not commissioned; nomination rejected by the Senate.

[12]Not commissioned; nomination rejected by the Senate.

[13]Took oath of office, but did not proceed to post in this capacity.

[14]Near the end of Bullitt's term of service, Anthony J. Drexel Biddle, Jr., acted as Deputy Ambassador to France, 13-25 June 1940

[15]S. Pinkney Tuck was serving as Chargé d'Affaires ad interim when France severed diplomatic relations with the U.S., 8 Nov. 1942.

[16]Embassy Paris was opened to the public 1 Dec. 1944 with Ambassador Caffery in charge pending presentation of his letter of credence.

France (*Continued*)

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
Arthur K. Watson	Conn.	NC	AE/P	8 Apr. 1970	6 May 1970	Left post, 30 Oct. 1972
John N. Irwin, II	N.Y.	NC	AE/P	2 Feb. 1973	23 Mar. 1973	Left post, 20 Oct. 1974
Kenneth Rush	N.Y.	NC	AE/P	19 Sept. 1974	21 Nov. 1974	Left post, 14 Mar. 1977
Arthur A. Hartman	N.J.	C	AE/P	8 June 1977	7 July 1977	Left post, 14 Oct. 1981
Evan Griffith Galbraith	Conn.	NC	AE/P	6 Nov. 1981	2 Dec. 1981	Left post, 15 July 1985
Joe M. Rodgers	Tenn.	NC	AE/P	19 July 1985	20 Sept. 1985	

Gabon[1]

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
W. Wendell Blancké[2]	Cal.	C	AE/P	12 Dec. 1960[r]. 6 Feb. 1961	13 Jan. 1961	Recommissioned after confirmation Superseded, 10 Oct. 1961
Charles F. Darlington	N.Y.	NC	AE/P	20 Sept. 1961	18 Oct. 1961	Left post, 26 July 1964
David M. Bane	Pa.	C	AE/P	22 July 1965	14 Aug. 1965	Left post, 29 June 1969
Richard Funkhouser	N.J.	C	AE/P	13 June 1969	9 Aug. 1969	Left post, 2 Aug. 1970
John A. McKesson, III	D.C.	C	AE/P	10 Dec. 1970	4 Feb. 1971	Left post, 1 June 1975
Andrew L. Steigman[3]	Md.	C	AE/P	10 June 1975	9 Aug. 1975	Left post, 21 Aug. 1977
Arthur T. Tienken	Va.	C	AE/P	3 Feb. 1978	6 Mar. 1978	Left post, 19 July 1981
Francis Terry McNamara	Vt.	C	AE/P	11 Dec. 1981	19 Jan. 1982	Left post, 3 Aug. 1984
Larry C. Williamson	Cal.	C	AE/P	13 Aug. 1984	20 Nov. 1984	Left post, 21 Aug. 1987
Warren Clark, Jr.	Conn.	C	AE/P	10 Aug. 1987	19 Sept. 1987	

[1]Alan W. Lukens (resident at Brazzaville) presented credentials as Chargé d'Affaires ad interim, 17 Aug. 1960. During Blancké's tenure as non-resident Ambassador, Embassy Libreville was established 20 Mar. 1961 with Walker A. Diamanti as Chargé d'Affaires ad interim.

[2]Accredited also to the Central African Republic, Chad, and Congo; resident at Brazzaville.

[3]Steigman and all subsequent Ambassadors were also accredited to the Democratic Republic of Sao Tomé and Principe and resident at Libreville.

The Gambia[1]

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
Mercer Cook[2]	Ill.	NC	AE/P	18 May 1965	9 Aug. 1965	Left Dakar, 1 July 1966
William R. Rivkin	Ill.	NC	AE/P	13 Oct. 1966	16 Jan. 1967	Died at Dakar, 19 Mar. 1967
L. Dean Brown	Md.	C	AE/P	18 Oct. 1967	18 Jan. 1968	Left Dakar, 15 Aug. 1970
G. Edward Clark	D.C.	C	AE/P	12 Oct. 1970	24 Nov. 1970	Left Dakar, 16 Oct. 1973
O. Rudolph Aggrey	D.C.	C	AE/P	23 Nov. 1973	17 Jan. 1974	Left Dakar, 10 July 1977
Herman J. Cohen	N.Y.	C	AE/P	24 June 1977	29 Mar. 1978	Left Dakar, 21 July 1980
Larry Gordon Piper	Tex.	C	AE/P	30 June 1980	21 Aug. 1980	Left post, 23 Aug. 1982[3]
Sharon Erdkamp Ahmad	D.C.	C	AE/P	30 Sept. 1982[4]		
Robert Thomas Hennemeyer	Ill.	C	AE/P	11 May 1984	20 June 1984	Left post, 27 June 1986
Herbert E. Horowitz	Fla.	C	AE/P	12 Sept. 1986	24 Oct. 1986	

[1]During Cook's tenure as non-resident Ambassador, Embassy Bathurst (now Banjul) was established 9 Sept. 1965 with John G. Gossett as Chargé d'Affaires ad interim.

[2]Ambassadors Cook through Cohen were also accredited to Senegal and resident at Dakar.

[3]Between Aug. 1982 and June 1984, the following officers served as Chargé d'Affaires ad interim: Owen W. Roberts, Aug. 1982-June 1983; P. Wesley Kriebel, July-Nov. 1983; Alan Logan, Nov. 1983-Apr. 1984; and Edward Brynn, May-June 1984.

[4]Did not serve under this appointment.

German Democratic Republic[1]

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
John Sherman Cooper	Ky.	NC	AE/P	19 Sept. 1974	20 Dec. 1974	Left post, 28 Sept. 1976
David B. Bolen	Colo.	C	AE/P	29 July 1977	22 Aug. 1977	Left post, 20 June 1980

[1]Embassy Berlin was established 9 Dec. 1974 with Brandon H. Grove, Jr., as Chargé d'Affaires ad interim.

Peru (*Continued*)

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
William D. Pawley	Fla.	NC	AE/P	14 June 1945	20 July 1945	Left post, 27 Apr. 1946
Prentice Cooper	Tenn.	NC	AE/P	2 May 1946	1 July 1946	Left post, 29 June 1948
Harold H. Tittmann, Jr.	Mo.	C	AE/P	18 June 1948	27 Sept. 1948	Left post, 30 Mar. 1955
Ellis O. Briggs	Me.	C	AE/P	24 Mar. 1955	27 Mar. 1955	Left post, 5 June 1956
Theodore C. Achilles	D.C.	C	AE/P	29 May 1956	24 July 1956	Relinquished charge, 27 Jan. 1960
Selden Chapin	D.C.	C	AE/P	18 Mar. 1960	7 May 1960	Left post, 7 Aug. 1960
James Loeb	N.Y.	NC	AE/P	18 Apr. 1961	23 May 1961	Normal relations interrupted 18 July 1962; new Govt. of Peru still unrecognized by the U.S. when Loeb left post, 26 July 1962
J. Wesley Jones	Ia.	C	AE/P	29 Nov. 1962[r] 27 Feb. 1963	6 Feb. 1963	Recommissioned after confirmation Left post, 2 June 1969
Taylor G. Belcher	N.Y.	C	AE/P	19 Aug. 1969	29 Aug. 1969	Left post, 4 Apr. 1974
Robert W. Dean	Ill.	C	AE/P	14 Mar. 1974	2 May 1974	Left post, 17 June 1977
Harry W. Shlaudeman	Cal.	C	AE/P	26 May 1977	28 June 1977	Left post, 20 Oct. 1980
Edwin Gharst Corr	Okla.	C	AE/P	2 Oct. 1980	6 Nov. 1980	Left post, 11 Oct. 1981
Frank V. Ortiz, Jr.	N.M.	C	AE/P	1 Oct. 1981	10 Nov. 1981	Left post, 27 Oct. 1983
David C. Jordan	Va.	NC	AE/P	1 Mar. 1984	20 Mar. 1984	Left post, 17 July 1986
Alexander F. Watson	Md.	C	AE/P	16 Oct. 1986	27 Nov. 1986	

Philippines

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
Paul V. McNutt	Ind.	NC	AE/P	21 June 1946	4 July 1946	Left post, 22 Mar. 1947
Emmet O'Neal	Ky.	NC	AE/P	10 June 1947	22 Sept. 1947	Left post, 28 Apr. 1948
Myron Melvin Cowen	N.Y.	NC	AE/P	2 Mar. 1949	23 May 1949	Left post, 14 Nov. 1951
Raymond Ames Spruance	Cal.	NC	AE/P	18 Jan. 1952	7 Feb. 1952	Left post, 1 Apr. 1955
Homer Ferguson	Mich	NC	AE/P	22 Mar. 1955	12 Apr. 1955	Left post, 23 Mar. 1956
Albert F. Nufer	N.Y.	C	AE/P	10 May 1956	20 July 1956	Died at post, 6 Nov. 1956
Charles E. Bohlen	D.C.	C	AE/P	9 May 1957	4 June 1957	Left post, 15 Oct. 1959
John D. Hickerson	Tex.	C	AE/P	13 Oct. 1959[r] 21 Jan. 1960	13 Jan. 1960	Recommissioned after confirmation Left post, 8 Dec. 1961
William E. Stevenson	Colo.	NC	AE/P	15 Dec. 1961[r] 30 Jan. 1962	5 Feb. 1962	Recommissioned after confirmation Left post, 14 June 1964
William McCormick Blair, Jr.	Ill.	NC	AE/P	8 June 1964	5 Aug. 1964	Left post, 21 Oct. 1967
G. Mennen Williams	Mich.	NC	AE/P	15 May 1968	17 June 1968	Left post, 7 Apr. 1969
Henry A. Byroade	Ind.	C	AE/P	22 July 1969	29 Aug. 1969	Left post, 25 May 1973
William H. Sullivan	R.I.	C	AE/P	16 July 1973	6 Aug. 1973	Left post, 26 Apr. 1977
David D. Newsom	Cal.	C	AE/P	21 Oct. 1977	11 Nov. 1977	Left post, 30 Mar. 1978
Richard W. Murphy	Va.	C	AE/P	25 May 1978	8 June 1978	Left post, 10 Aug. 1981
Michael Hayden Armacost	Md.	NC	AE/P	11 Feb. 1982	12 Mar. 1982	Left post, 18 Apr. 1984
Stephen Warren Bosworth	Mich.	C	AE/P	12 Apr. 1984	4 May 1984	Left post, 2 Apr. 1987
Nicholas Platt	D.C.	C	AE/P	10 Aug. 1987	27 Aug. 1987	

Poland

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
Hugh S. Gibson	Cal.	C	EE/MP	[16 Apr. 1919[1]] 26 June 1919	2 May 1919	Recommissioned after confirmation Presented recall, 3 May 1924
Alfred J. Pearson	Ia.	NC	EE/MP	2 Apr. 1924	26 June 1924	Left post, 18 Aug. 1925
John B. Stetson, Jr.	Pa.	NC	EE/MP	3 July 1925[r] 17 Dec. 1925	29 Aug. 1925	Recommissioned after confirmation Left post, 29 Aug. 1929
Alexander P. Moore[2]	Pa.	NC	AE/P	31 Jan. 1930		
John N. Willys	O.	NC	AE/P	8 Mar. 1930	24 May 1930	Left post, 30 May 1932
F. Lammot Belin	Pa.	C	AE/P	2 Nov. 1932[r]	13 Dec. 1932	Recess appointment expired, 4 Mar. 1933

[1]Commission (issued during a recess of the Senate) not of record; took oath of office on this date.

[2]Died in the U.S. before taking oath of office.

Poland (*Continued*)

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
James Michael Curley[3]	Mass.	NC	AE/P			
John Cudahy	Wis.	NC	AE/P	13 June 1933	6 Sept. 1933	Left post, 23 Apr. 1937
Anthony J. Drexel Biddle, Jr.[4]	Pa.	NC	AE/P	4 May 1937	2 June 1937	Left London, 1 Dec. 1943[5]
Arthur Bliss Lane	N.Y.	C	AE/P	21 Sept. 1944	4 Aug. 1945	Left post, 24 Feb. 1947
Stanton Griffis	Conn.	NC	AE/P	15 May 1947	9 July 1947	Left post, 21 Apr. 1948
Waldemar J. Gallman	N.Y.	C	AE/P	7 July 1948[r] 2 Mar. 1949	15 Oct. 1948	Recommissioned after confirmation Left post, 8 July 1950
Joseph Flack	Pa.	C	AE/P	20 Sept. 1950	30 Nov. 1950	Left Poland, 22 Apr. 1955
Joseph E. Jacobs	S.C.	C	AE/P	1 Apr. 1955	23 May 1955	Left post, 23 July 1957
Jacob D. Beam	N.J.	C	AE/P	26 June 1957	9 Aug. 1957	Left post, 30 Nov. 1961
John M. Cabot	D.C.	C	AE/P	30 Jan. 1962	2 Mar. 1962	Left post, 24 Sept. 1965
John A. Gronouski	Wis.	NC	AE/P	11 Sept. 1965	7 Dec. 1965	Left post, 26 May 1968
Walter J. Stoessel, Jr.	Cal.	C	AE/P	24 July 1968	12 Sept. 1968	Left post, 5 Aug. 1972
Richard T. Davies	Wyo.	C	AE/P	2 Dec. 1972[r] 8 Feb. 1973	5 Jan. 1973	Recommissioned after confirmation Left post, 5 Feb. 1978
William E. Schaufele, Jr.	O.	C	AE/P	3 Feb. 1978	30 Mar. 1978	Left post, 11 Sept. 1980
Francis J. Meehan	D.C.	C	AE/P	2 Oct. 1980	27 Oct. 1980	Left post, 11 Feb. 1983[6]
John R. Davis, Jr.[7]	Cal.	C	AE/P	5 Feb. 1988	17 Mar. 1988	

[3]Not commissioned; nomination withdrawn before the Senate acted upon it.

[4]Biddle left Warsaw, 5 Sept. 1939, and followed the Govt. of Poland first to France (Sept. 1939-June 1940) and later to England (where Biddle arrived 14 Mar. 1941). Rudolf E. Schoenfeld opened the Embassy near the Govt. of Poland established in England, making his initial call as Chargé d'Affaires ad interim on 21 Sept. 1940. Biddle was commissioned also to Belgium, Czechoslovakia, Greece, Luxembourg, the Netherlands, Norway, and Yugoslavia; resident at London during his service near those govts.

[5]Rudolf E. Schoenfeld was serving as Chargé d'Affaires ad interim when the mission of the Embassy near the Govt. of Poland established in England was terminated, 5 July 1945. He closed the office at London on 31 July 1945, on which date Embassy Warsaw was established with Ambassador Lane in charge pending presentation of his letter of credence.

[6]The following officers have since served as Chargé d'Affaires ad interim: Herbert E. Wilgis, Jr., Feb.-July 1983; and John R. Davis, Jr., Sept. 1983-Jan. 1987.

[7]Designated Chargé d'Affaires 9 Jan. 1987.

Portugal

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
David Humphreys	Conn.		MR	21 Feb. 1791	13 May 1791	Presented recall, 25 July 1797
John Quincy Adams[1]	Mass.		MP	30 May 1796		
William Smith	S.C.		MP	10 July 1797	8 Sept. 1797	Presented recall, 9 Sept. 1801
Thomas Sumter, Jr.[2]	S.C.		MP	7 Mar. 1809	7 June 1810	Presented recall, 24 July 1819
John Graham[3]			MP	6 Jan. 1819	24 July 1819	Left Rio de Janeiro, 13 June 1820
John James Appleton[4]	Mass.		CdA			
Henry Dearborn, Sr.	Mass.		EE/MP	7 May 1822	[5]	Had farewell audience, 30 June 1824
Thomas L. L. Brent	Va.		CdA	9 Mar. 1825	24 June 1825 18 Jan. 1830	Reaccredited after change of govt. Left post on or soon after 28 Nov. 1834
Edward Kavanagh	Me.		CdA	3 Mar. 1835	25 July 1835	Relinquished charge, 19 Apr. 1841
Washington Barrow	Miss.		CdA	16 Aug. 1841	28 Dec. 1841	Presented recall, 20-24 Feb. 1844
Abraham Rencher	NC		CdA	22 Sept. 1843[r] 11 Jan. 1844	20-24 Feb. 1844	Recommissioned after confirmation Presented recall, 4 Nov. 1847
George W. Hopkins	Va.		CdA	3 Mar. 1847	4 Nov. 1847	Presented recall, 18 Oct. 1849
James Brown Clay	Ky.		CdA	1 Aug. 1849[r] 18 Mar. 1850	18 Oct. 1849	Recommissioned after confirmation Left post, 19 Aug. 1850
Charles B. Haddock	N.H.		CdA	10 Dec. 1850	17 June 1851	Presented recall, 16 June 1854
John L. O'Sullivan[6]	N.Y.		CdA MR	16 Feb. 1854 29 June 1854	16 June 1854 19 Oct. 1854	Promoted to MR Presented recall, 15 July 1858

[1]Did not serve under this appointment.

[2]Served at the court of Portugal in Brazil; resident at Rio de Janeiro.

[3]Served at the court of Portugal in Brazil; resident at Rio de Janeiro.

[4]Not commissioned; nomination to be Chargé d'Affaires at Rio de Janeiro rejected by the Senate. Appleton, however, served as Chargé d'Affaires ad interim from June 1820 until the Legation to Portugal at Rio de Janeiro was closed in 1821 (his last dispatch dated 12 July 1821).

[5]Arrived at Lisbon before 16 Aug. 1822; did not report date of presentation of credentials.

[6]Nominated 25 Feb. 1856 to be EE/MP; nomination withdrawn before the Senate acted upon it.

Honduras (*Continued*)

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
Julius G. Lay	D.C.	C	EE/MP	16 Dec. 1929	31 May 1930	Left post, 17 Mar. 1935
Leo J. Keena	Mich.	C	EE/MP	22 Feb. 1935	19 July 1935	Left post, 1 May 1937
John D. Erwin	Tenn.	NC	EE/MP	29 July 1937	8 Sept. 1937	Promoted to AE/P
			AE/P	27 Mar. 1943	27 Apr. 1943	Left post, 16 Apr. 1947
Paul C. Daniels	N.Y.	C	AE/P	10 Apr. 1947	23 June 1947	Left post, 30 Oct. 1947
Herbert S. Bursley	D.C.	C	AE/P	18 Dec. 1947	15 May 1948	Left post, 12 Dec. 1950
John D. Erwin	Tenn.	NC	AE/P	1 Feb. 1951	14 Mar. 1951	Left Honduras, 28 Feb. 1954
Whiting Willauer	Mass.	NC	AE/P	5 Feb. 1954	5 Mar. 1954	Left post, 24 Mar. 1958
Robert Newbegin	N.H.	C	AE/P	26 Mar. 1958	21 Apr. 1958	Left post, 3 Aug. 1960
Charles R. Burrows	O.	C	AE/P	27 Aug. 1960	3 Nov. 1960	Left post, 28 June 1965
Joseph J. Jova	N.Y.	C	AE/P	7 June 1965	12 July 1965	Left post, 21 June 1969
Hewson A. Ryan	Mass.	C	AE/P	9 Oct. 1969	5 Nov. 1969	Left post, 30 May 1973
Phillip V. Sanchez	Cal.	NC	AE/P	24 May 1973	15 June 1973	Left post, 17 July 1976
Ralph E. Becker	D.C.	NC	AE/P	13 Sept. 1976	27 Oct. 1976	Left post, 1 Aug. 1977
Mari-Luci Jarimillo	N.M.	NC	AE/P	26 Sept. 1977	27 Oct. 1977	Left post, 19 Sept. 1980
Jack Robert Binns	Ore.	C	AE/P	26 Sept. 1980	10 Oct. 1980	Left post, 31 Oct. 1981
John Dimitri Negroponte	N.Y.	C	AE/P	29 Oct. 1981	11 Nov. 1981	Left post, 30 May 1985
John Arthur Ferch	O.	C	AE/P	18 July 1985	22 Aug. 1985	Left post, 9 July 1986
Everett Ellis Briggs	N.H.	C	AE/P	16 Oct. 1986	4 Nov. 1986	

Hungary[1]

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
U. Grant-Smith	Pa.	C	CdA pro tem	[2]	24 Jan. 1922	Left post, 28 Apr. 1922
Theodore Brentano	Ill.	NC	EE/MP	10 Feb. 1922	16 May 1922	Presented recall, 6 May 1927
J. Butler Wright	Wyo.	C	EE/MP	26 Feb. 1927	18 June 1927	Presented recall, 24 Oct. 1930
Nicholas Roosevelt	N.Y.	NC	EE/MP	29 Sept. 1930[r]	12 Nov. 1930	Recommissioned after confirmation
				16 Dec. 1930		Left post, 9 May 1933
John Flournoy Montgomery	Cal.	NC	EE/MP	13 June 1933	1 Aug. 1933	Left post, 17 Mar. 1941
Herbert Claiborne Pell	R.I.	NC	EE/MP	11 Feb. 1941	20 May 1941	Hungary severed diplomatic relations with the U.S., 11 Dec. 1941[3]
H. F. Arthur Schoenfeld	D.C.	C	EE/MP	15 Dec. 1945	26 Jan. 1946	Left post, 1 June 1947
Selden Chapin	D.C.	C	EE/MP	10 Apr. 1947	9 July 1947	Declared persona non grata by Govt. of Hungary, 11 Feb. 1949[4]
Nathaniel P. Davis	N.J.	C	EE/MP	1 Sept. 1949	21 Oct. 1949	Left post, 18 May 1951
Christian M. Ravndal	Ia.	C	EE/MP	3 Oct. 1951	11 Jan. 1952	Left post, 5 Aug. 1956
Edward T. Wailes[5]	D.C.	C	EE/MP	26 July 1956		
Martin J. Hillenbrand	Ill.	C	AE/P	13 Sept. 1967	30 Oct. 1967	Left post, 15 Feb. 1969
Alfred Puhan	Va.	C	AE/P	1 May 1969	16 June 1969	Left post, 9 July 1973
Richard F. Pedersen	Cal.	NC	AE/P	24 July 1973	10 Sept. 1973	Left post, 26 Mar. 1975
Eugene V. McAuliffe	Mass.	C	AE/P	25 Mar. 1975	28 Apr. 1975	Left post, 15 Apr. 1976
Philip Mayer Kaiser	N.Y.	NC	AE/P	7 July 1977	4 Aug. 1977	Left post, 9 Mar. 1980
Harry E. Bergold, Jr.	Fla.	C	AE/P	3 Mar. 1980	31 Mar. 1980	Left post, 9 Nov. 1983
Nicolas M. Salgo	Fla.	NC	AE/P	7 Oct. 1983	23 Nov. 1983	Left post, 1 Aug. 1986
Robie M.H. Palmer	Vt.	C	AE/P	24 July 1986	8 Dec. 1986	

[1]See under Austria for representatives to Austria-Hungary.

[2]Not commissioned; letter of credence dated 27 Dec. 1921. Legation Budapest was established 26 Dec. 1921, on which date Grant-Smith was granted provisional recognition as Chargé d'Affaires.

[3]Hungary declared war on the U.S., 13 Dec. 1941. Pell left post, 16 Jan. 1942.

[4]Chapin left post, 17 Feb. 1949

[5]Took oath of office and proceeded to post, but did not present credentials; left post, 27 Feb. 1957. During the period 1957-1967 each of the following officers served as Chargé d'Affaires ad interim for more than a year: Garret G. Ackerson, Jr., July 1957-Feb. 1961; Horace G. Torbert, Jr., Feb. 1961-Dec. 1962; Owen T. Jones, Dec. 1962-July 1964; Elim O'Shaughnessy, Nov. 1964-Sept. 1966; Richard W. Tims, Sept. 1966-Oct. 1967. Tims was serving as Chargé d'Affaires ad interim when Legation Budapest was raised to Embassy status, 28 Nov. 1966.

Nepal (*Continued*)

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
Chester Bowles	Conn.	NC	AE/P	10 Oct. 1951	16 Feb. 1952	Left New Delhi, 23 Mar. 1953
George V. Allen	N.C.	C	AE/P	11 Mar. 1953	5 July 1953	Left New Delhi, 30 Nov. 1954
John Sherman Cooper	Ky.	NC	AE/P	4 Feb. 1955	3 June 1955	Left New Delhi, 23 Apr. 1956
Ellsworth Bunker	Vt.	NC	AE/P	28 Nov. 1956[r] 25 Jan. 1957	 8 Mar. 1957	Recommissioned after confirmation Superseded, 25 Nov. 1959
Henry E. Stebbins	Mass.	C	AE/P	9 Sept. 1959	25 Nov. 1959	Left post, 10 June 1966
Carol C. Laise	D.C.	C	AE/P	19 Sept. 1966	5 Dec. 1966	Left post, 5 June 1973
William I. Cargo	Fla.	C	AE/P	16 July 1973	28 Sept. 1973	Left post, 3 Apr. 1976
Marquita M. Maytag	Cal.	NC	AE/P	3 Mar. 1976	18 May 1976	Left post, 22 Apr. 1977
L. Douglas Heck	Ore.	C	AE/P	26 May 1977	29 July 1977	Left post, 19 May 1980
Philip R. Trimble	N.Y.	NC	AE/P	23 May 1980	10 July 1980	Left post, 21 Feb. 1981
Carleton S. Coon, Jr.	N.H.	C	AE/P	11 June 1981	3 July 1981	Left post, 3 Aug. 1984
Leon Jerome Weil	N.Y.	NC	AE/P	13 Aug. 1984	21 Sept. 1984	Left post, 11 Nov. 1987
Milton Frank	Cal.	NC	AE/P	28 Mar. 1988	22 Apr. 1988	

Netherlands

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
John Adams[1]	Mass.		MP	1 Jan. 1781	[19 Apr. 1782[2]]	Transmitted recall by note from London, 30 Mar. 1788[3]
William Livingston[4]	N.J.		MP			
John Rutledge[5]	S.C.		MP			
William Short	Va.		MR	16 Jan. 1792	18 June 1792	Left post, 19 Dec. 1792
John Quincy Adams[6]	Mass.		MR	30 May 1794	6 Nov. 1794	Presented recall, 20 June 1797
William Vans Murray[7]	Md.		MR	2 Mar. 1797	20 June 1797	Presented recall, 2 Sept. 1801
William Eustis	Mass.		EE/MP	19 Dec. 1814	[20 July 1815[8]]	Had farewell audience, 5 May 1818
Alexander H. Everett	Mass.		CdA	27 June 1818[r] 30 Nov. 1818	 4 Jan. 1819	Recommissioned after confirmation Had farewell audience, 7 Apr. 1824
Christopher Hughes[9]	Md.		CdA	9 Mar. 1825	10 July 1826	Superseded, 28 Jan. 1830
William Pitt Preble	Me.		EE/MP	1 June 1829[r] 10 Feb. 1830	28 Jan. 1830	Recommissioned after confirmation Left post on or shortly before 2 May 1831
Auguste Davezac	La.		CdA	15 Oct. 1831[r] 3 Jan. 1832	30 Dec. 1831	Recommissioned after confirmation Superseded, 13 July 1839
Harmanus Bleecker	N.Y.		CdA	15 May 1839[r] [19 Mar. 1840[10]]	13 July 1839	Recommissioned after confirmation Superseded, 22 Aug. 1842
Christopher Hughes	Md.		CdA	12 May 1842	22 Aug 1842	Presented recall, 28 June 1845
Auguste Davezac	La.		CdA	19 Apr. 1845[r] 3 Feb. 1846	28 June 1845	Recommissioned after confirmation Superseded, 16 Sept. 1850
George Folsom	N.Y.		CdA	4 May 1850[11]	16 Sept. 1850	Presented recall, 11 Oct. 1853
August Belmont[12]	N.Y.		CdA MR	24 May 1853[r] 8 Feb. 1854 29 June 1854	11 Oct. 1853 26 Sept. 1854	Recommissioned after confirmation Promoted to MR Presented recall, 22 Sept. 1857
Henry C. Murphy	N.Y.		MR	1 June 1857[r] 14 Jan. 1858	24 Sept. 1857	Recommissioned after confirmation Presented recall, 8 June 1861
James S. Pike	Me.		MR	28 Mar. 1861	8 June 1861	Left post on or soon after 29 May 1866
Daniel E. Sickles[13]	N.Y.		MR	11 May 1866		
John A. Dix[14]	N.Y.		MR	27 July 1866		
Albert Rhodes			CdA	[15]	19 Oct. 1866	Superseded, 1 Dec. 1866

[1]Commissioned also to Great Britain (see under United Kingdom); resident at London after 1785. Adams also received a second set of instructions dated 16 Aug. 1781.

[2]Formally recognized on this date.

[3]Adams, before leaving The Hague at the end of his longest period of residence there, presented Charles W. F. Dumas as Chargé d'Affaires ad interim on 15 Oct. 1782. Dumas, although holding no commission from the United States, continued to act in this capacity, except during Adams' later visits to the Netherlands, until 1790.

[4]Elected 23 June 1785 to be MP to the United Netherlands; declined appointment.

[5]Elected 5 July 1785 to be MP to the United Netherlands; declined appointment.

[6]Continued to serve, without reaccreditation, after the proclamation of the Batavian Republic.

[7]Commissioned to the Batavian Republic.

[8]Formally received on this date.

[9]Nominated 11 Dec. 1828 to be EE/MP; nomination tabled by the Senate.

[10]Commission not of record, but enclosed with an instruction of this date.

[11]The record copy is so dated, but the date is probably erroneous, as the Senate confirmed Folsom's nomination on 14 May 1850.

[12]Nominated 25 Feb. 1856 to be EE/MP; nomination withdrawn before the Senate acted upon it.

[13]Declined appointment.

[14]Declined appointment.

[15]Not commissioned; letter of credence dated 29 Sept. 1866.

Netherlands (*Continued*)

Name	Res.	Career	Title	Appointment	Pres. of Cred.	Term. of Mission
Hugh Ewing	Kans.		MR	24 Sept. 1866[r] 2 Mar. 1867	1 Dec. 1866	Recommissioned after confirmation Left post on or soon after 31 Oct. 1870
Joseph P. Root[16]	Kans.		MR			
Charles T. Gorham	Mich.		MR	12 July 1870	15 Dec. 1870	Presented recall, 9 July 1875
Francis B. Stockbridge[17]	Mich.		MR	12 July 1875[r]		
James Birney	Mich.		MR	10 Jan. 1876	29 Mar. 1876	Left post on or soon after 20 Apr. 1882
William L. Dayton	N.J.		MR	26 Apr. 1882	26 Sept. 1882	Presented recall, 8 June 1885
Isaac Bell, Jr.	R.I.		MR	2 Apr. 1885	8 June 1885	Presented recall, 29 Apr. 1888
Robert B. Roosevelt	N.Y.		MR	16 May 1888	10 Aug. 1888	Promoted to EE/MP
			EE/MP	10 Aug. 1888	26 Sept. 1888	Presented recall, 17 May 1889
Samuel R. Thayer	Minn.		EE/MP	19 Mar. 1889	24 May 1889	Presented recall, 7 Aug. 1893
William E. Quinby	Mich.		EE/MP	24 May 1893[r] 25 Aug. 1893	11 Aug. 1893	Recommissioned after confirmation Presented recall, 26 July 1897
Stanford Newel[18]	Minn.		EE/MP	11 May 1897	19 Aug. 1897	Recommissioned to a combination of countries
				5 June 1903[r] 16 Nov. 1903		Recommissioned after confirmation Presented recall, 30 June 1905
David J. Hill[19]	N.Y.		EE/MP	15 Mar. 1905	15 July 1905	Presented recall, 1 June 1908
Arthur M. Beaupré	Ill.		EE/MP	2 Apr. 1908	15 June 1908	Transmitted recall by note, 25 Sept. 1911
Lloyd Bryce	N.Y.		EE/MP	12 Aug. 1911	16 Nov. 1911	Presented recall, 10 Sept. 1913
Henry van Dyke	N.J.	NC	EE/MP	27 June 1913	15 Oct. 1913	Presented recall, 11 Jan. 1917
John W. Garrett	Md.	C	EE/MP	23 Aug. 1917	11 Oct. 1917	Left post, 18 June 1919
William Phillips	Mass.	C	EE/MP	3 Mar. 1920	23 Apr. 1920	Left post, 11 Apr. 1922
Richard M. Tobin	Cal.	NC	EE/MP	27 Feb. 1923[20] 5 Mar. 1923[r] 12 Dec. 1923	1 May 1923	Recommissioned after confirmation Left post, 29 Aug. 1929
Gerrit John Diekema	Mich.	NC	EE/MP	11 Sept. 1929	20 Nov. 1929	Died at post, 20 Dec. 1930
Laurits S. Swenson	Minn.	NC	EE/MP	28 Feb. 1931	29 Apr. 1931	Left post, 5 Mar. 1934
Grenville T. Emmet[21]	N.Y.	NC	EE/MP	27 Dec. 1933[r] 15 Jan. 1934	21 Mar. 1934	Left post, 21 Aug. 1937
George A. Gordon	N.Y.	C	EE/MP	30 July 1937	10 Sept. 1937	Govt. left the Netherlands, 13 May 1940, in anticipation of German occupation.[22]
Anthony J. Drexel Biddle, Jr.[23]	Pa.	NC	EE/MP	11 Feb. 1941	27 Mar. 1941	Promoted to AE/P
			AE/P	12 May 1942	[8 May 1942[24]]	Left London, 1 Dec. 1943
Stanley K. Hornbeck[25]	Colo.	NC	AE/P	21 Sept. 1944	8 Dec. 1944	Left post, 7 Mar. 1947
Herman B. Baruch	N.Y.	NC	AE/P	13 Mar. 1947	12 Apr. 1947	Left post, 26 Aug. 1949
Selden Chapin	D.C.	C	AE/P	7 Oct. 1949	27 Oct. 1949	Left post, 30 Oct. 1953
H. Freeman Matthews	D.C.	C	AE/P	1 Oct. 1953[r] 26 Jan. 1954	25 Nov. 1953	Recommissioned after confirmation Left post, 11 June 1957
Philip Young	N.Y.	NC	AE/P	28 Mar. 1957	27 June 1957	Left post, 20 Dec. 1960
John S. Rice	Pa.	NC	AE/P	29 Mar. 1961	6 May 1961	Left the Netherlands, 27 May 1964
William R. Tyler	D.C.	C	AE/P	6 May 1965	23 June 1965	Left post, 20 June 1969
J. William Middendorf II	Conn.	NC	AE/P	13 June 1969	9 July 1969	Left post, 10 June 1973
Kingdon Gould, Jr.	Md.	NC	AE/P	28 Sept. 1973	18 Oct. 1973	Left post, 30 Sept. 1976
Robert J. McCloskey	Pa.	C	AE/P	3 Sept. 1976	22 Oct. 1976	Left post, 10 Mar. 1978
Geri M. Joseph	Minn.	NC	AE/P	18 July 1978	6 Sept. 1978	Left post, 17 June 1981
William Jennings Dyess	Ala.	C	AE/P	30 July 1981	2 Sept. 1982	Left post, 19 July 1983
L. Paul Bremer III	Conn.	C	AE/P	6 July 1983	31 Aug. 1983	Left post, 25 Aug. 1986
John Shad	D.C.	NC	AE/P	15 June 1987	24 June 1987	

[16]Not commissioned; nomination withdrawn before the Senate acted upon it.

[17]Took oath of office, but did not proceed to post.

[18]Newel's second and third commissions were to the Netherlands and Luxembourg; resident at The Hague.

[19]Representatives from Hill through Phillips were also accredited to Luxembourg and resident at The Hague.

[20]Commissioned to the Netherlands and Luxembourg; did not serve under this appointment. His later commissions were to the Netherlands only.

[21]Did not serve under this appointment.

[22]Gordon closed the Legation, 15 July 1940, and left post, 16 July 1940. Rudolf E. Schoenfeld established the Legation near the Govt. of the Netherlands established in England, making his initial call as Chargé d'Affaires ad interim on 15 Aug. 1940.

[23]Served near the Govt. of the Netherlands established in England; commissioned also to Belgium, Czechoslovakia, Greece, Luxembourg, Norway, Poland, and Yugoslavia; resident at London.

[24]Formally received, and the Legation raised to Embassy status, on this date.

[25]Served near the Govt. of the Netherlands established in England; resident first at London; transferred the Embassy to The Hague, 17 Aug. 1945. The office of the Embassy in London was closed, 19 Sept. 1945.

Dams in the Delta

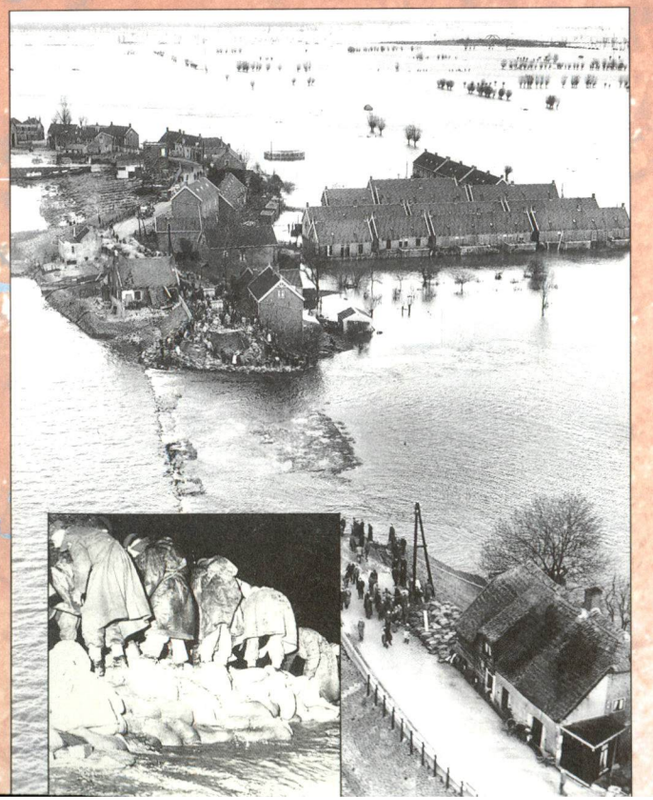


The last dam in the Delta Project was completed in the spring of 1987 and lies at the junction of the provinces of Zeeland, North Brabant and South Holland. Its completion marked the end of thirty years' construction work on a chain of dams and other hydraulic engineering works to protect the southwest Netherlands from flooding.

The vulnerability of the Netherlands

Over half of the Netherlands lies below sea level. Just how vulnerable the country is to flooding was demonstrated on the night of 1 February 1953. The combination of a spring tide and a persistent, violent northwesterly storm recreated on a particularly large scale an event which happened many times over the centuries. Waves destroyed the dykes and the sea rushed into the polders. The results were catastrophic: 1,835 people drowned and many thousands of cows, horses, pigs and chickens were killed. The floods destroyed 47,000 homes, as well as schools, churches and other buildings. Approximately 500 kilometres of dykes were completely or partially destroyed and 200,000 hectares of land was flooded. The hardest hit areas were the province of Zeeland, the southern part of South Holland and the western part of North Brabant.

The bewilderment and shock felt by people in the rest of the Netherlands when they learnt of the extent of the flooding soon gave way to determination, and great efforts were made to reseal the breached dykes. The last breach, near Ouwerkerk on Schouwen-Duiveland, was resealed at the beginning of November 1953. Rarely have the people of the Netherlands been so united as when they decided that such a catastrophe should never happen again.



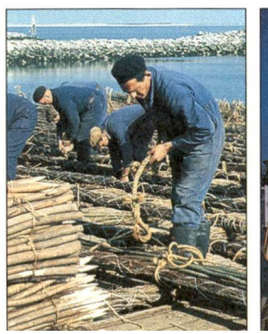
The Delta Project

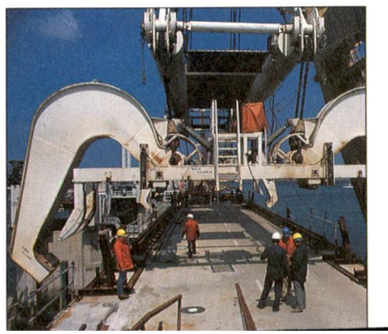
The outcome of this determination was the Delta Project. The Project's principal goal was to improve the safety of the southwest Netherlands by considerably shortening and reinforcing the coastline. It was decided that dams should be constructed across inlets and estuaries, considerably reducing the possibility of the sea surging into the land once more. Freshwater lakes would form behind them. Roads along the dams would improve access to the islands of Zeeland and South Holland. Dams could not be constructed across the New Waterway or the Western Scheldt, as these important shipping routes to the seaports of Rotterdam and Antwerp had to be kept open. The safety of these areas was to be guaranteed by substantially reinforcing the dykes.

The Delta Project is one of the largest hydraulic engineering projects that has ever been carried out anywhere in the world. New hydraulic engineering techniques were gradually developed for the construction of the eleven dams and barriers of various sizes which were built over a period of thirty years.

In the early 1970s the realization grew that it was important to preserve as much of the natural environment as possible, and this point of view has left its mark on the Delta Project. As a result the original plans were changed: not all of the inlets, distributaries and estuaries between the Western Scheldt and the New Waterway have been transformed into freshwater lakes as was initially intended; there are now very distinct water systems, each with its own characteristic function.

You can now drive along the roads constructed on top of the dams and visit all the major Delta works and water systems in a single day. It does not matter where your journey begins or which direction you take. There is no systematic route one could follow to visit the dams and barriers in the same sequence in which the project was carried out. Yet the Delta Project was carried out in anything but a random order. Work began on the relatively simpler parts, so that the experience gained could be used during the construction of larger, more difficult dams across inlets and estuaries with strong tidal currents. That was how the Delta works progressed: new hydraulic engineering techniques were first applied on a small scale and then used in the larger projects.





1 The Hollandse IJssel

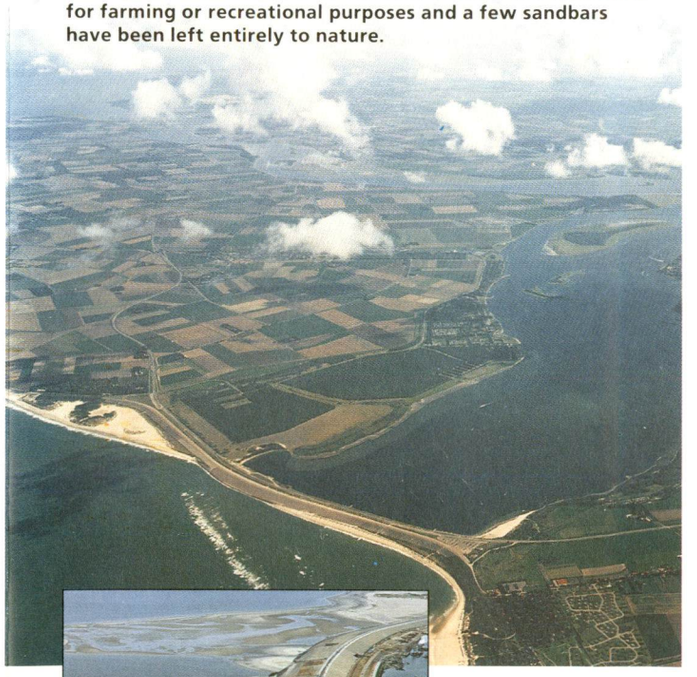
Engineers from the Public Works Department first turned their attention to the Hollandse IJssel, a river with an open passage to the sea via the Nieuwe Maas. A storm surge barrier was built at Krimpen to protect one of the lowest lying and most densely populated areas of the Netherlands. Under normal conditions, the gates of the barrier, which was completed in 1958, are raised 12 metres above the waterlevel, so that there is no obstruction to shipping. If the tide rises to a dangerously high level, the gates can be lowered to dam the river. A lock allows ships to travel up or downstream when the barrier is closed.



2 The Veerse Meer

After the storm surge barrier in the Hollandse IJssel was completed, a start was made on the first major dams in the turbulent tidal inlets. In line with the principle of working from small to large, the first project was the Three Islands Project, which entailed the construction of dams in the Zandkreek between North and South Beveland and in the Veerse Gat between North Beveland and Walcheren. During the construction of the Zandkreek dam asphalt was used for the first time to cover the sill which would support the caissons, huge concrete structures which can be positioned quickly to dam the tidal inlet. The Zandkreek dam was completed in 1960.

The seven caissons used a year later to dam the Veerse Gat were even larger. Sluices in the caissons allowed the tide to ebb and flow without obstruction. This prevented the current from becoming too strong while the mouth of the channel was gradually being dammed. When all seven were in position the steel sluice gates were closed simultaneously and the caissons filled with sand. A substantial part of the dam had already been built on a sandbar in the Veerse Gat by pumping sand onto it. The Veerse Meer, the lake formed after the dam was completed, is partly brackish due to dilution by rainwater. Land that has been reclaimed is now used for farming or recreational purposes and a few sandbars have been left entirely to nature.



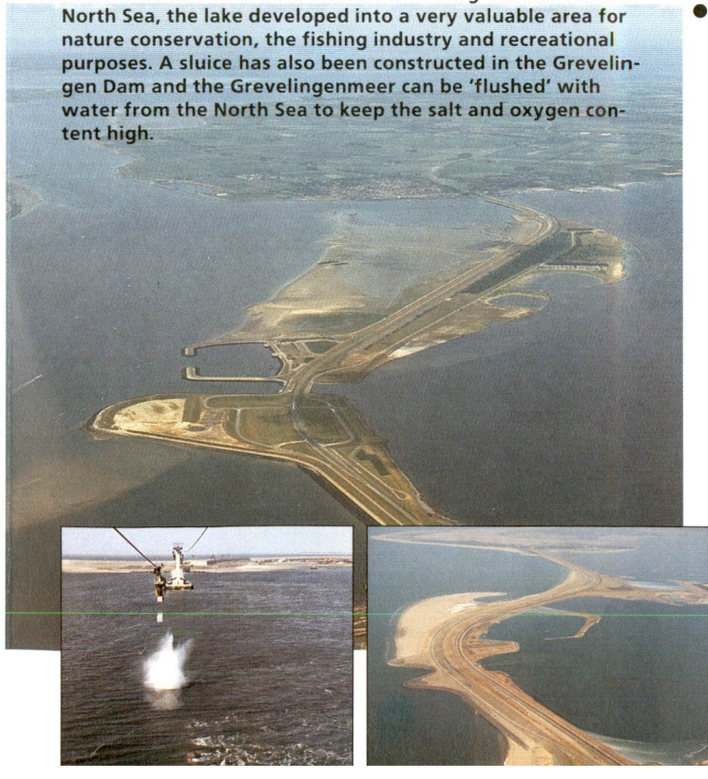


3 The Grevelingenmeer

● The construction of the Grevelingen dam (completed in 1965) entailed a more extensive use of the seabed protection techniques that had been tested in the Zandkreek and the Veerse Gat. The six-kilometre dam between Schouwen-Duiveland and Goeree-Overflakkee crosses the channels on either side of the Oude Tong sandbar. The section on the sandbar itself was built by pumping sand onto it. The southern channel was dammed using the same type of small caissons that had been used in the Zandkreek dam, but a new technique was developed for the larger channel to the north: a cableway was spanned across the channel and cable cars tipped stone into the water.

A substantial part of the dam built across the Brouwershavense Gat, which forms the western boundary of the Grevelingenmeer, was also constructed on sandbars using the pumping method. The northern channel was dammed with sluice caissons. These remained open until the dam in the southern channel, which was constructed using a cableway, had risen well above the water level. Then the sluice gates were closed and the dam across the two tidal channels was completed using sand.

★ The Brouwers dam was completed in 1971, and the area behind it is now a lake, the Grevelingenmeer. The loss of the tide and the gradual reduction in the salt content of the water led to the death of many plants and animals. Within a few years, though, nature adapted to the new conditions. After a sluice had been constructed in the Brouwers dam to allow water to flow between the Grevelingenmeer and the North Sea, the lake developed into a very valuable area for nature conservation, the fishing industry and recreational purposes. A sluice has also been constructed in the Grevelingen Dam and the Grevelingenmeer can be 'flushed' with water from the North Sea to keep the salt and oxygen content high.



4 The Haringvliet

The Volkerak dam separates the Hollandsch Diep and the Haringvliet from the southern part of the Delta and prevents fresh water from the Rhine and the Maas flowing southward. The Volkerak dam, completed in 1965, comprises the Hellegatsplein, a dam extending to Goeree-Overflakkee and a second dam with a large lock complex extending in the direction of North Brabant. A road bridge has been built from the Hellegatsplein to the Hoekse Waard. The dam to Goeree-Overflakkee was built with pumped sand. Twelve sluice caissons were needed to dam the southeastern channel.

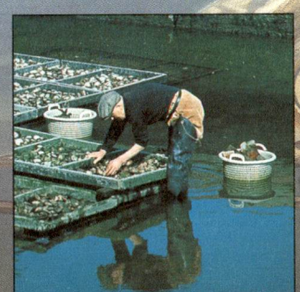
The Haringvliet dam on the western side of the Haringvliet has two purposes. It must not only protect the waters inland from high tides, but must also discharge excess water from the Rhine and the Maas. The construction of the 4.5 kilometre Haringvliet dam therefore began with the building of a large sluice complex. The 17 sluices can discharge an enormous volume of water. Closing or opening the sluices determines how much water has to be discharged by the alternative route via the New Waterway. By channelling as much water as possible through the New Waterway to the North Sea, saltwater is prevented from penetrating deep inland and making the groundwater saline. The sluice complex in the Haringvliet dam is called the 'tap of the Netherlands' because of its vital significance to the country's water management. The channel on the southern side of the discharge sluices was dammed with sand, and that on the northern side using the cableway method. The dam was completed in 1971. There is now no tide in the Haringvliet and it consist entirely of freshwater.



5 The Eastern Scheldt

While the Haringvliet dam and the Brouwers dam were nearing completion, preparations had already begun for the construction of the dam across the mouth of the Eastern Scheldt, the last, largest and also most complex part of the Delta Project. Three islands were constructed: Roggenplaat, Neeltje Jans and Noordland. A pumped sand dam was built between the latter two. In the remaining channels the first steel towers were built for the cableway, as it was planned to dam the Eastern Scheldt using this well-tried method. Its completion date was set for 1978.

At the end of the 1960s however protests were voiced about the project. Scientists became aware of the special significance of the flora and fauna in and around the Eastern Scheldt. The sandbars and mud flats exposed at low tide are important feeding grounds for birds, and the estuary is a nursery for fish from the North Sea. Fishermen and action groups made sure that the scientific findings were heard by the government and parliament. A heated debate flared up. Opponents of the dam believed that the safety of the region could be guaranteed by raising the height of the dykes along the Eastern Scheldt. The inlet would then remain open and saline. The equally vigorous supporters of the solid dam, for example agricultural and water boards, appealed to the emotions of the Zeelanders, asking whether the consequences of the flood disaster of 1953, had already been forgotten.





6 The Storm Surge Barrier

A compromise was reached in 1976: a storm surge barrier, which would stay open under normal conditions but which could be closed at very high tides. The construction of the storm surge barrier meant a break with the policy that the Public Works Department and the hydraulic engineering contractors in the Netherlands had pursued in working from small to large and from relatively simple to complex. The storm surge barrier needed expertise that had yet to be developed and experience that had yet to be gained. Extensive research was carried out to determine the feasibility of building the storm surge barrier, taking full account of the interests of the environment, flood protection, and the fishing and shipping industries.
The actual construction of the storm surge barrier also had to be thoroughly studied. The solution was a barrier consisting of pre-fabricated concrete and steel components that were assembled in the three channels at the mouth of the Eastern Scheldt. 65 colossal concrete piers from the barrier's backbone. A stone sill and a concrete sill beam were placed between each of the piers, and the openings could be closed with steel gates. Concrete box girders were placed on top of the piers to form a road deck.

The seabed also needed special consideration. A new technique was required to prevent the strong current in the mouth of the river from washing away the sand on which the piers were to stand. The solution was to place the piers on mattresses filled with graded layers of sand and gravel which would allow water to flow through but trap the sand.



The construction of the storm surge barrier also required the development of special equipment. The 'Mytilus' made its appearance in the estuary to compact the seabed, followed by the 'Jan Heijmans' which laid asphalt and dumped stones, the 'Cardium' which positioned the mattress, the 'Ostrea' to lift, transport and position the piers and the mooring and cleaning pontoon 'Macoma'. These are very special ships designed for just one purpose: to construct the storm surge barrier. New measuring instruments and computer programs were also developed, so that engineers working 30 to 40 metres below the surface could position components with such precision that the maximum error would be just one centimetre.

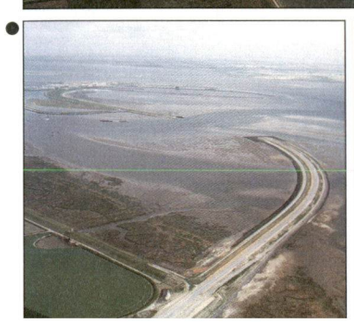
The Cardium laid the first mattress in November 1982 and the Ostrea placed the first pier in August 1983. Work progressed quickly. There were virtually no technical setbacks; only the cost turned out to be higher than expected. The storm surge barrier was 30% more expensive than estimated. On 4 October 1986 Her Majesty Queen Beatrix officially opened the storm surge barrier. The Eastern Scheldt has remained open and flood protection has been achieved. On average the barrier has to be closed once a year because of storms.

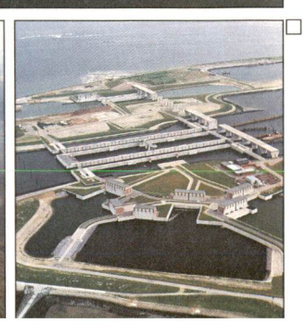


The Zoommeer

The storm surge barrier has narrowed the mouth of the Eastern Scheldt, and less water now enters and leaves the estuary with the tide. Special measures had to be taken to ensure that this reduction in tidal movement would not lead to a serious reduction in the difference between the high and low water levels. Partly for this reason two dams were built in the Eastern Scheldt inland of the storm surge barrier. These reduced the area of the estuary and ensured an adequate tidal range despite the construction of the storm surge barrier. Behind these two dams, the Oester dam and the Philips dam, an area of fresh water has formed with a permanent water level, the long Krammer/Volkerak and the Zoommeer. Another reason for constructing the Oester and Philips dams was that shipping on this important route would no longer be affected by tidal movements. Furthermore, these dams prevent fresh water from entering the salt water of the Eastern Scheldt. The size of the Zoommeer was reduced by the completion of the Markiezaat dyke in 1983 and a canal was excavated to discharge excess fresh water from the lake into the Western Scheldt. The protection provided by the storm surge barrier allowed the Oester dam and the Philips dam to be constructed entirely of sand. Tidal currents in the estuary can largely be eliminated by closing the barrier's gates. The Oester dam was completed in 1986 and the Philips dam in the following year. The Philips dam has an unusual lock complex with a salt/freshwater separation system that prevents salt water entering the freshwater lake and fresh water entering the Eastern Scheldt whenever a ship passes through the locks.







The Monument

The place where the Philips dam joins up with the Grevelingen dam is typical of the Delta works. It is a point where three different water systems meet: the saltwater Grevelingenmeer, the freshwater Krammer/Volkerak and the estuary of the Eastern Scheldt, each with its own environment and its own function. The concrete anchor block, which was part of the cableway used in the construction of the Grevelingen dam, has been left as a monument to the new hydraulic engineering techniques that have been developed. The dams themselves symbolise the safety that the Delta Project has brought to the southwest Netherlands.

More Information

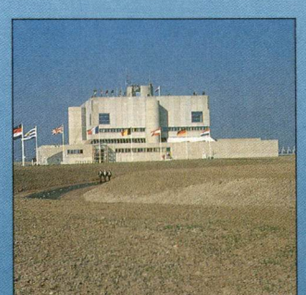
A permanent exhibition on the Delta Project and the history of flood defences in the Netherlands – the Delta Expo – is housed in the Topshuis on the island Neeltje Jans in the mouth of the Eastern Scheldt.

Colophon

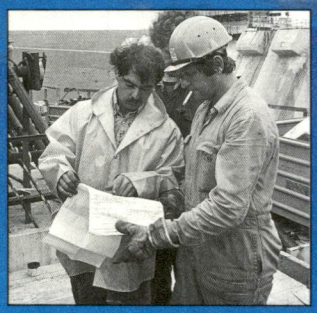
Ministry of Transport and Public Works
Information Division
Plesmanweg 5 – Den Haag
june 1988

Design: Dijkerman & van Waarden, Den Haag

Photography: Aerocamera, Bart Hofmeester

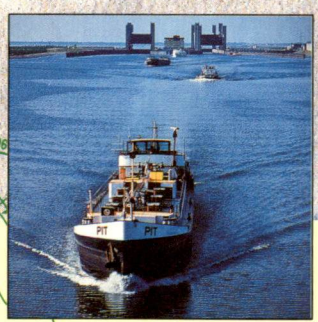


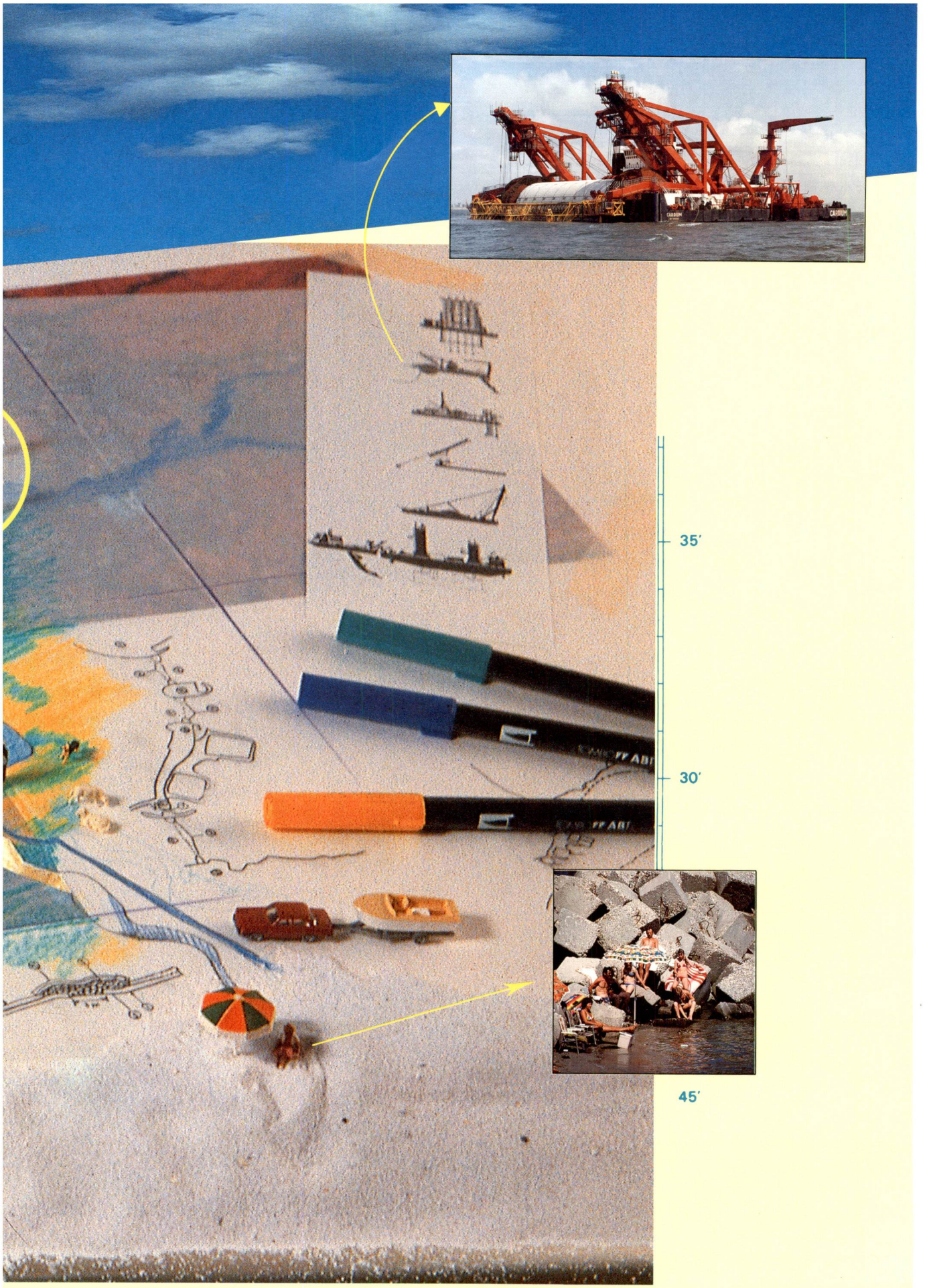




The Delta Project

preserving the environment and securing Zeeland against flooding




35′
30′
45′
40′

The Delta Project

preserving the environment and securing Zeeland against flooding

Countless floods



The flood disaster of 1953 claimed 1,835 lives

The sea has had many opportunities in the past to determine the shape of the Netherlands. The line of coastal defences shows where the water overpowered the people. Every century has witnessed floods. Many were given names, for example the *Saint Aechten's Day Flood in* 1288, *the Saint Elizabeth's Day Floods in* 1404 *and* 1421, *the Saint Felix's Day Flood in* 1530 *and All Saints' Day Flood in* 1570. Although the Dutch fought back, they often had to surrender large areas of land to the sea. *The Verdronken Land van Saeftinghe* (Zeeland Flanders), *the Verdonken Land van Reimerswaal* (South Beveland) and *Zuidland* (Schouwen-Duiveland), for example, were all lost to the sea. On balance, during the past centuries more land has been lost than reclaimed.

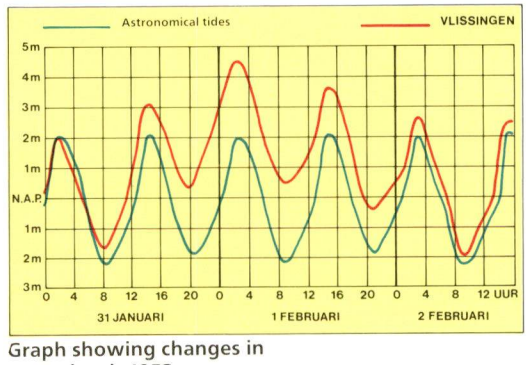
Floods have not been confined to particular periods or enabled to occur only by the limitations of technology. They have also occurred in the 20th century, for instance in 1906 and 1916. The greatest flood disaster in the country's history occurred on the night of 1 February 1953. The sea surged into many polders in the southwest Netherlands, innundating some 200,000 hectares of fertile farmland and flooding many towns and villages. The dykes were destroyed in 67 places and breached in over 400. 1,835 people drowned and 72,000 were forced to evacuate the region; more than 200,000 cows, horses, pigs and other livestock died and over 47,000 buildings were damaged.

The dykes had not been equal to the unprecedentedly high water level of 4 to 5 metres above AOD (Amsterdam Ordnance Datum, mean sea level as defined for Amsterdam). The flood was caused by a spring tide, when exceptionally low and high tides are produced as the influences of the sun and moon reinforce each other, in combination with a persistent northwesterly storm. The storm reached its peak in the middle of the night, and an hour of continuous wind force 12 coincided with the high tide. The water piled up against the dykes, spilled over the top of them and then began to wash them away. Most people were asleep when the sea overtook them.



The dikes break in many places

A great deal of assistance was offered from abroad. The people of the Netherlands were determined not to surrender the flooded land. Their thoughts first turned to repairing the damage and then to preventing a reoccurrence of such a disaster. They quickly resealed the dykes and pumped the water out of the polders. The experience they had gained in pumping the island of Walcheren dry after the bombing of its dykes in 1944, in damming the Brielse Maas in 1950 and in damming the Braakman inlet in 1952 proved invaluable. Caissons, large watertight concrete structures, were indispensable as a means of blocking off the channels quickly. The last breach, near Ouwerkerk, was resealed in November 1953.



Graph showing changes in water levels 1953

The attractions of delta regions



he mud flats are a eeding ground for wading birds

People have always been attracted to coastal regions. River estuaries in particular are obvious places for settlements; the river provides a communication route to the hinterland and also supplies alluvium that forms fertile soil. The distributaries that branch from a river as it approaches the sea often form a triangular shape on the map. The mouth of the river Nile in Egypt is a very good example of this. The ancient Greeks called the mouth of the Nile a "delta" after the fourth letter of their alphabet, which was written in the form of a triangle. Nowadays the term delta is widely used to describe many areas where a river enters a sea or a lake. Apart from the Nile, other famous deltas include those of the Ganges, the Mississippi, the Rhone and the Yangtze. In the southwest Netherlands the estuaries of the Rhine, Maas and Scheldt also form a delta.

Low, flat deltas are vulnerable regions, and the inhabitants have good cause to construct dykes and embankments to protect themselves against the sea. As villages and towns flourish, though, and their economic importance as centres of trade, shipping and industry increases, the need to construct better forms of protection also increases.

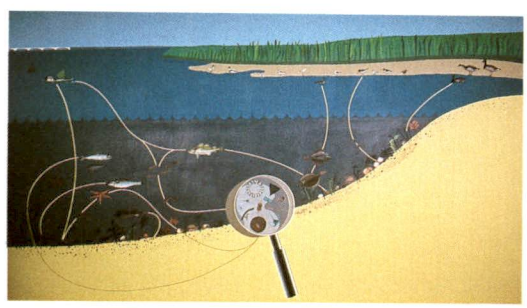
Deltas often provide many of the conditions needed to support a rich and varied system of plant and animal communities. Algae and plants grow in the shallow, relatively warm water, which light can penetrate easily. Their growth and the supply of organic matter from the sea and minerals from the river enable deltas to act as nurseries for young fish. The driving force behind the delta's ecosystem is the tide. The regular exposure of mud flats and sandbars at low tide and their submergence at high tide is indispensable to the innumerable shellfish, worms and other fauna that live on them. These in turn are essential to the thousands of birds that feed on them at low tide. The lower animals and birds form a small food chain, one of the many that exist in the water, the mud flats and the higher-lying salt marshes.

However, the human settlement, transportation, agriculture, fishing, trade and industry that flourish due to the favourable conditions of the delta are a threat to the ecosystem. The increasing size of ships requires the dredging of deeper navigation channels and the construction of larger harbours. Industry discharges waste into the water, and toxins discharged hundreds of kilometres upstream eventually settle with the alluvium at the mouth of the river. Human activities put the ecosystem under pressure. Since the beginning of the 1970s there has been a growing awareness that this pressure cannot continue to increase unabated and that a balance needs to be struck between the interests of ecology and the economy.

ds abound in the Dutch delta

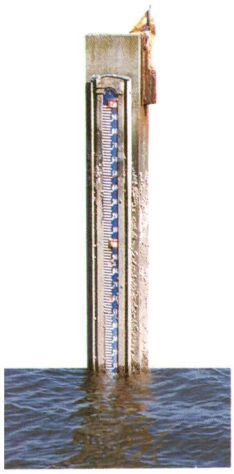
od chain in the astern Scheldt

oyster, a popular cy from the waters of the delta



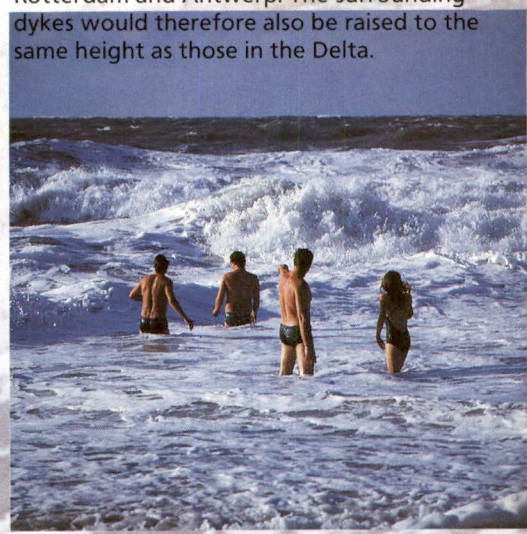


Securer flood defences



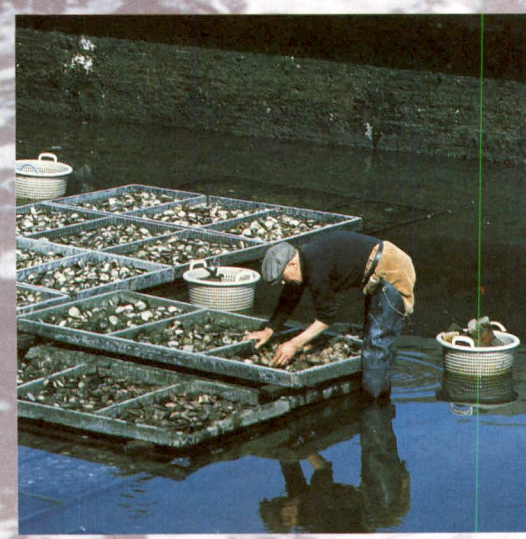
Shortly after the 1953 flood a specially appointed committee presented proposals for the prevention of another disaster in the future. The proposals centred on improving safety by strengthening the coastal defences. A proposal to shorten the length of the coastline was enthusiastically received, as, after all, the strength of a defensive line increases as its length decreases. This has been the principle behind many other hydraulic engineering works, an outstanding example of which is the Barrier Dam which was constructed in 1932 across the mouth of the *Zuyder Zee,* now called the *IJsselmeer,* to protect it from the incursions of the North Sea. By constructing this single dam, the length of the coastline was reduced by 300 kilometres and the danger of flooding in a large area of the country was entirely eliminated.

The committee recommended that the tidal channels in the Rhine, Maas and Scheldt Delta should be dammed near the coast and that the dykes along the sea and the rivers in the rest of the country should be raised to allow for a water level of five metres above AOD at the Hook of Holland. This would reduce the frequency of inland flooding to an average of once every ten thousand years and flooding in the inlets to once every four thousand years, which seemed quite safe enough for the time being. The *New Waterway* and the *Western Scheldt* had to be kept open to shipping due to their economic importance to the ports of Rotterdam and Antwerp. The surrounding dykes would therefore also be raised to the same height as those in the Delta.



In 1958, Parliament passed the Delta Act, which set out plans to ensure the safety of the southwest Netherlands, to the great enthusiasm of the public. In addition to reducing the risk of flooding by increasing the height of the dykes and shortening the coastline by 700 kilometres, the Delta Project would also create considerable economic benefits. It would improve water management in a large proportion of the Netherlands and combat the penetration of salt water into the ground water. Freshwater lakes would form and be an important source of water for farms. New recreational areas, particularly for water sports, would be created. The construction of dams would also considerably improve the road network in the southwest Netherlands.

One of the Project's drawbacks was that the saltwater fishing industry and the shellfish farms would disappear. The oyster and mussel farms centred on the town of Yerseke were an important source of income in the *Eastern Scheldt* region, but would be destroyed after the inlets were dammed. Shellfish cultivation would have to be transferred to other areas. In those days very little consideration was paid to the environment; flood protection and the economy were the main issues.



The sea walls must be able to hold back water levels of 5 meters + Normal Amsterdam Level (NAP)

Oyster beds in Yerseke

New water sport areas created by the Delta Plan

Fewer dykes

The original plans for the Delta Project entailed the construction of huge dams in four tidal inlets, the *Veerse Gat*, the *Eastern Scheldt*, the *Brouwershavense Gat* and the *Haringvliet*, which would reduce the length of the sea-dykes in the region from over 700 kilometres to just 25 kilometres. In addition, three dams were also planned further inland in the *Volkerak*, *Grevelingen* and *Zandkreek* channels. The *Volkerak* dam would separate the freshwater and saltwater environments, and the dams in the *Grevelingen* and *Zandkreek* would eliminate uncontrollable currents in the tidal area.

Some unusual civil engineering structures would be needed for specific purposes. A storm surge barrier was to be built in the *Hollandse IJssel* to protect the low-lying but densely-populated region of South Holland. A large sluice complex was to be built in the *Haringvliet dam* to discharge any excess water from the Rhine and the Maas into the North Sea. Locks were also to be built in several dams for commercial ships and pleasure craft.



crammer locks in the Philips Dam

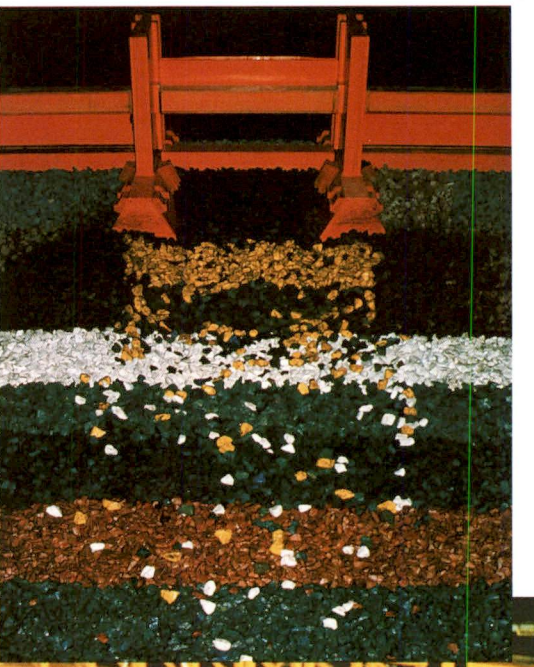
rds eye view of the estern delta area

New techniques

The Delta Project was a challenge to Dutch hydraulic engineers. It was evident that past experience and existing techniques would not be sufficient to enable dams to be constructed across the wide and deep tidal channels. The tidal range in the Delta is approximately three metres and the water flows in and out twice a day with powerful currents shifting enormous quantities of sand. Weather conditions in the estuaries are often unfavourable and North Sea storms produce powerful waves. New techniques had to be developed quickly so that the Delta Project could be carried out.

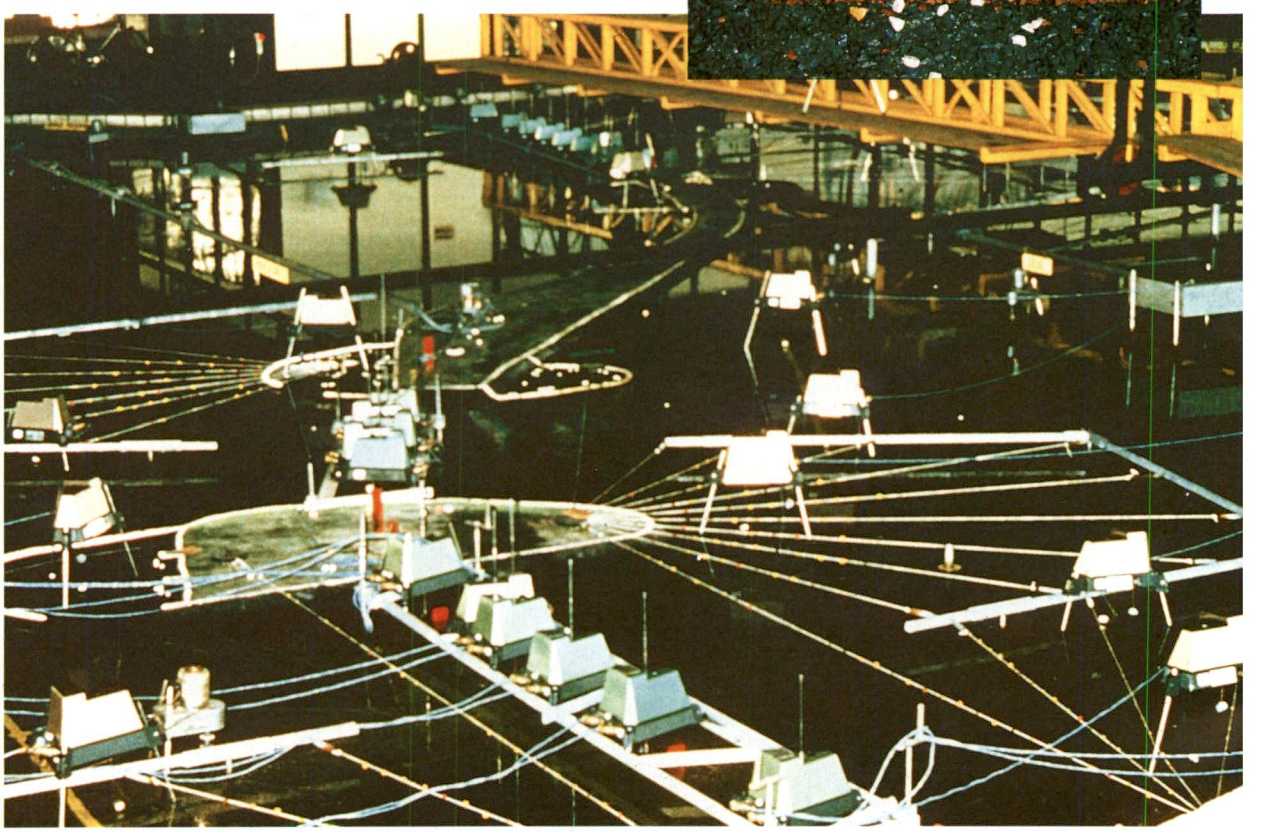
The towering caissons were adapted and improved. Man-made fibres were used for the first time to protect the seabed and to clad the dykes. The traditional seabed protection method, which involved covering the seabed with large osier mats made of willow wood and weighted with stone, was gradually replaced. Changes took place step by step. It was decided to implement the Delta Project by working from small to large so that technological progress would keep pace with the growth in experience.

Prefabrication became a common technique and in addition to new materials, new equipment was also very valuable. Sluice caissons were developed. A cableway with gondolas was developed to tip stone into the channels. Hydrodynamic study techniques were refined by developing laboratory tests. The computer gradually made its entrance. Measuring techniques and weather forecasts became more accurate. The Delta Project would take 25 years to complete. A new age was dawning for hydraulic engineering.

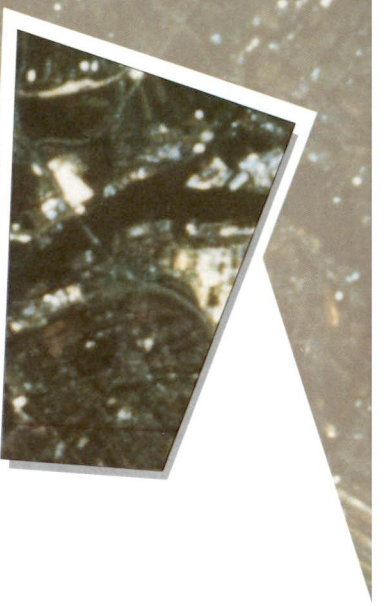


Scale model in the hydrodynamic laboratory

Model of storm flood barrier currents



The implementation of the Delta Project



1

The storm surge barrier in the Hollandse IJssel 1958

The implementation of the Delta Project began with the construction of a storm surge barrier across the river the Hollandse IJssel, which forms an open passageway to the sea via the Nieuwe Maas. The barrier was built just to the east of Rotterdam and completed in 1958. It protects the lowest-lying region of the Netherlands from flooding. The 80 metre wide barrier consists of four piers towering over 44 metres above AOD, two gates suspended between the piers, a shipping lock and a road bridge. Under normal conditions the gates are raised high above the water so as not to impede shipping, but when the water level is dangerously high they can be lowered, effectively damming the river. When the barrier is closed ships can pass through the lock.

torm flood barrier in the Hollandse IJssel



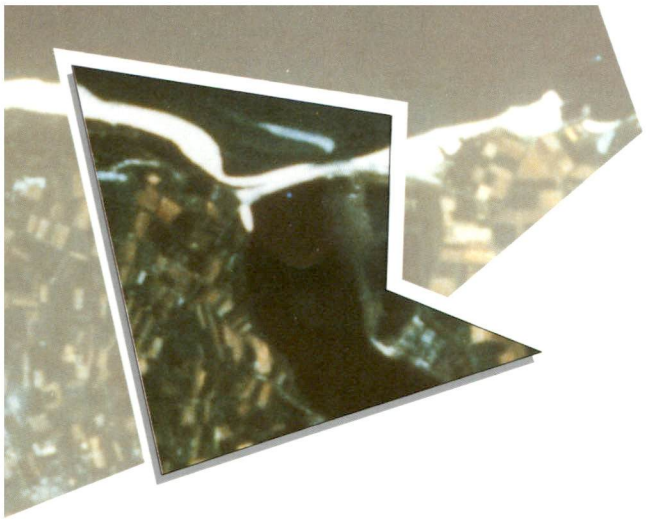


2 The Zandkreek dam 1960

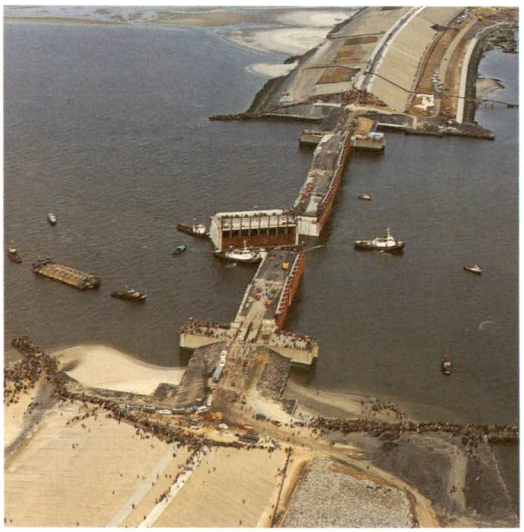
The Delta Project really got underway with the construction of the dams. First on the agenda was the Three Islands Project, which would connect the islands of Walcheren, North Beveland and South Beveland with each other. Work began in 1959 on a dam with a lock between North and South Beveland in the Zandkreek channel. The 830 metre long dam was constructed using caissons and completed in May 1960. By this date the construction of the dam across the Veerse Gat between Walcheren and North Beveland was progressing well. Around 70 million m^3 of water flowed through the Veerse Gat with each tide.



The Zandkreek Dam with lock







Veerse Gatdam

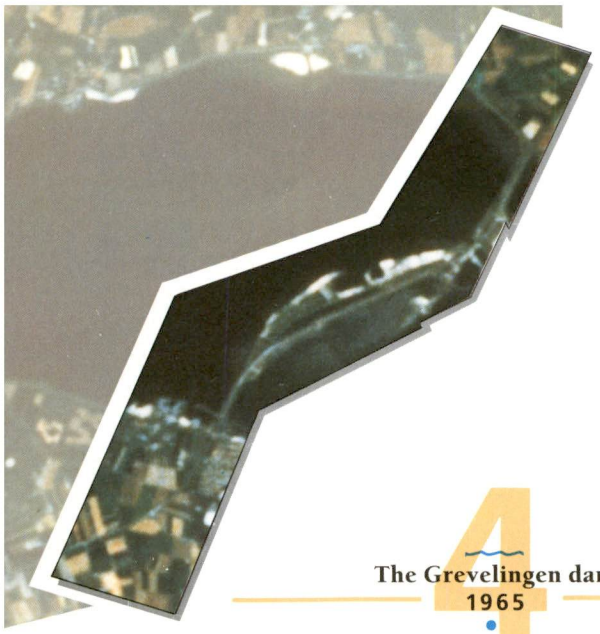
e last caisson is almost
lace at the Veerse Gat
Dam

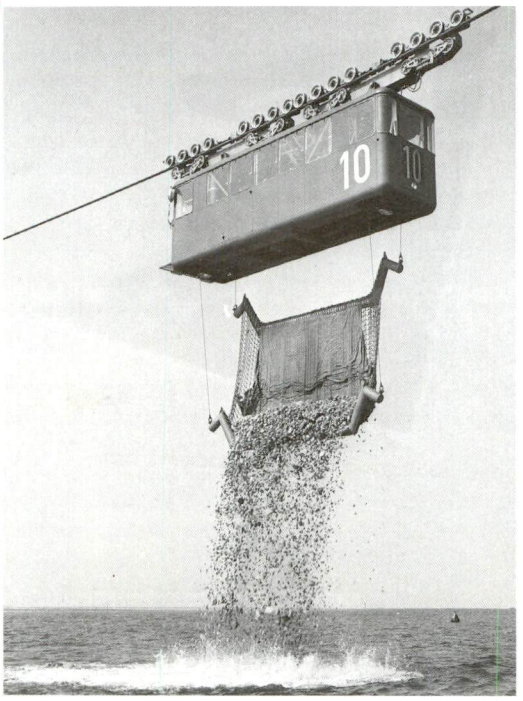
n open caisson being
ansported to the last
gap in the dike

3 The Veerse Gat dam 1961

A new technique was needed to dam the Veerse Gat. The usual caissons were adapted and what are known as sluice caissons were developed. Sluice caissons have sealable openings so that at first water can flow through them freely while a dam is being constructed. Seven sluice caissons, each as high as a seven-storey building, were placed in the 320 metre wide channel on a sill made of tipped stone. The dam was completed in April 1961. The sluices were closed at slack water between low and high tide. The closure of the first inlet had been completed and a lake, the Veerse Meer, had been created. A dyke was quickly laid over the caissons to finish the work.









4 The Grevelingen dam 1965

A start had been made in 1958 on the six-kilometre dam across the Grevelingen channel between Schouwen-Duiveland and Goeree-Overflakkee, which would ultimately incorporate a lock and harbours near Bruinisse. A substantial part of the dam was constructed on the Oude Tonge sandbar using the well-tried method of dredging sand. Two channels remained open. The small southern channel was dammed using solid caissons placed on a sill constructed from new materials - nylon and mastic asphalt. A new method was used to dam the larger, northern channel: a cableway with gondolas suspended from steel cables nine centimetres thick was spanned across the channel and used to gradually dam it by tipping 170,000 tons of stone. The dam was completed in 1965 and a road along the top opened to traffic.

Cableway above Grevelingen

'assageway through the Grevelingen Dam

Bulldozers and diggers on the future Grevelingen Dam



The Volkerak locks



5

The Volkerak dam
1969

Taking advantage of the new techniques, the Volkerak channel between the Haringvliet and Hollandsch Diep channels was dammed to improve water management and the transport network. The work, which commenced in 1957, consisted of a dam across the Hellegatsplaten (a series of sandbars) and the Hellegatsplein (an artificial island), a bridge spanning the 1200 metres across the Haringvliet, and a large lock and sluice complex and a solid dam at the mouth of the Volkerak. The dam across the Hellegatsplaten and Hellegatsplein, the Hellegats dam, was constructed entirely of sand. The Volkerak was dammed in the spring of 1969 using 12 sluice caissons. By that date the locks, built near the town of Willemstad, were already being used by ships on the busy Scheldt-Rhine shipping route.



6 The Haringvliet dam 1971

It took 14 years to construct the Haringvliet dam, which extends 4.5 kilometres between Goeree and Voorne. A unique design was developed as the dam had to remain open for the purposes of water management and the discharge of excess water from the Maas and the Rhine: a sluice complex with a channel width of 1,000 metres and a lock for fishing boats. The 17 sluices can be closed with steel gates on both the sea and the river side. The gates were made in an excavated construction site surrounded by an encircling dyke - similar to a polder - in the middle of the Haringvliet. The sluice complex temporarily functioned as sluice caissons, and the dam was completed in 1970 by tipping 100,000 concrete blocks using a cableway. A road built along the dam was opened in 1971.



Trench with Haringvliet sluices under construction



Drainage sluices in the Haringvliet Dam

Brouwers Dam

Cableway at the Brouwershavense Gat





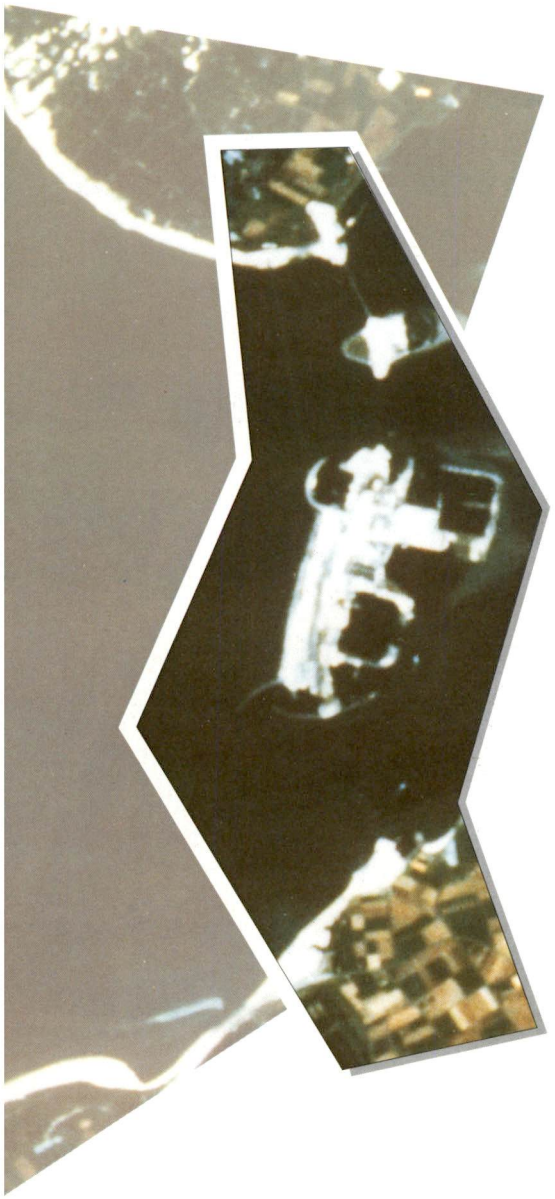


7

The Brouwers dam
1971

The final rehearsal for the last part of the Delta Project, the Eastern Scheldt, was the construction of a dam across the 6.5 kilometre wide and 30 metre deep Brouwershavense Gat between Goeree and Schouwen. Work began in 1962 using various well-tried methods. Sand dams were dredged on the shallow Kabbelaarsbank and Middelplaten sandbars. The northern channel, Springersdiep, was dammed using sluice caissons, which had been constructed in a special construction dock in the Grevelingen. The southern channel, the Brouwershavense Gat, was dammed using the cableway method. The dam was completed at the end of 1971, creating a new lake, the Grevelingenmeer. A sluice was built into the dam ten years after its completion in order to flush the Grevelingenmeer with water from the North Sea to keep the salt content of the lake at an appropriate level.

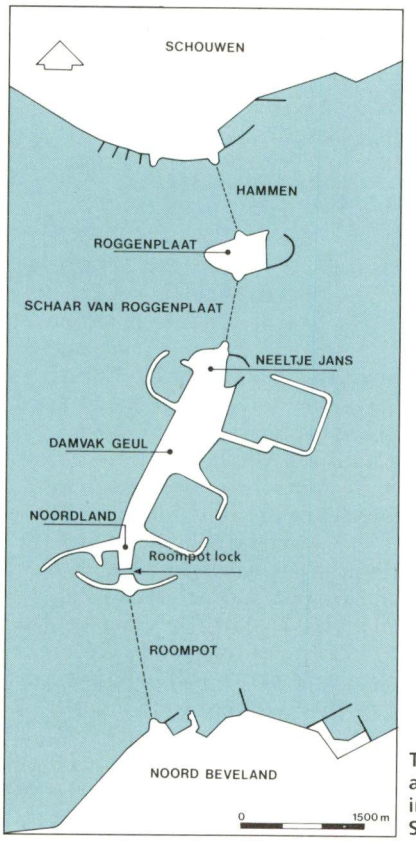
The most difficult project



The Eastern Scheldt dam, 1986

According to the original plans the dam across the mouth of the Eastern Scheldt inlet would have been completed in 1978, 25 years after the flood disaster. The construction of this dam, extending eight kilometres between Schouwen and North Beveland, would be the most difficult part of the Delta Project. The inlet had an average tidal range of three metres and its deepest channel was 40 metres deep. 1,100 million m^3 of water flowed through the channels at each tide, considerably more than the 350 million m^3 that flowed through the Brouwershavense Gat. Work commenced in 1967. The construction islands Roggenplaat, Neeltje Jans and Noordland were built on three shallow sandbars. Neeltje Jans and Noordland were later linked to each other by a three-kilometre dam.

Approximately five kilometres of the dam had been completed by the end of 1973. Three channels remained open, the Hammen, Schaar van Roggenplaat and Roompot channels, with a total width of three kilometres. According to the plans they were to be dammed using the cableway method and prefabricated concrete blocks. Steel towers for the cableway had already been erected in the channels, but they were never to be used. There was an increasing body of public opinion in the Netherlands which felt that the Eastern Scheldt should remain open to conserve the environment and the fishing industry. Social pressure forced though a radical change in the Delta Project.



Tidal channels and damextensions in the Eastern Scheldt

Increasing environmental awareness

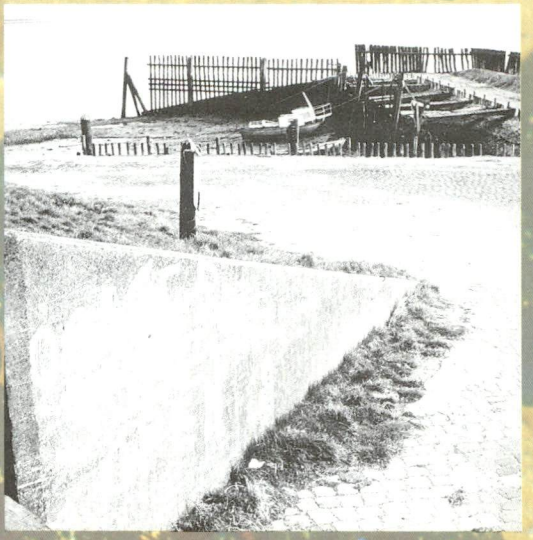


Sting-ray

The technical progress that had been achieved during the implementation of the Delta Project had not occurred in isolation. There had been a general and rapid growth in the economies of the western industrialised nations. Standards of living and levels of consumption had increased. The growth of opportunities, knowledge and power seemed to know no bounds. Cities were expanding, the road network was growing constantly, communications links were bringing far-away places closer to home and man was walking on the moon. With its emphasis on flood protection, increases in scale and the use of the very latest techniques, the Delta Project was a part of this era.

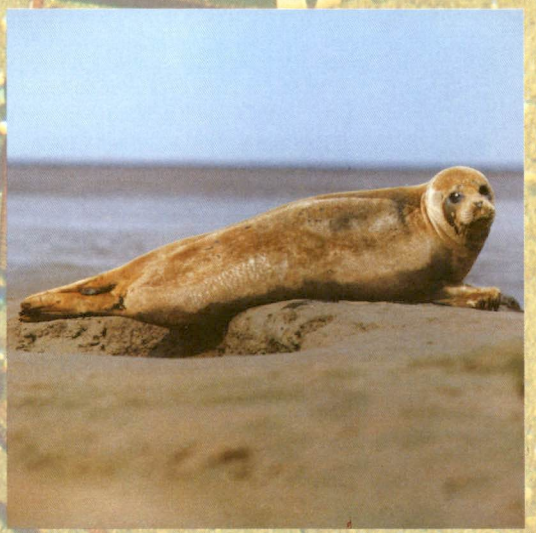
In the second half of the 1960s opinions about the environment changed. There was a growing awareness that the global assault on the environment could have catastrophic results. The idea gained ground that there had to be limits to growth, and the optimistic view of the future began to fade. This ultimately led to a fresh approach being adopted for the Delta Project. The construction of a solid dam across the mouth of the *Eastern Scheldt* lost the general support it had once commanded. If the dam were built, the *Eastern Scheldt* would no longer be a tidal inlet, the salt water would become fresh and instead of rising and falling with the tides the water level would be constant. Moreover, the plant and animal communities would be transformed and the shellfish would disappear. More and more people realised that the *Eastern Scheldt* was an area of exceptional value and became concerned about the effects that damming the inlet would have on the flora and fauna.

Scientists, nature conservationists and fishermen spearheaded the protest against a solid dam. Their alternative was to raise the height of the surrounding dykes. Politicians initially refused to consider the plans. They had promised to dam the *Eastern Scheldt*, and they would keep their word. The fight to keep the *Eastern Scheldt* open, however, gradually received wider support, even in political circles. How people believed the inlet should be made safe became a yardstick for measuring their environmental awareness. The government decided to commission a special committee to perform a new study. In 1974 the committee recommended a compromise: the *Eastern Scheldt* should be kept open most of the time but closed whenever there was a risk of flooding.





Hermit crab



Seals return to the
astern Scheldt estuary

The Eastern Scheldt
estuary holds an
abundance of lobster

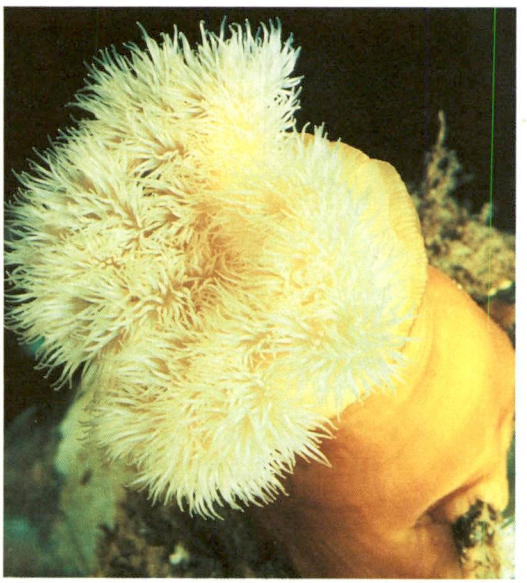
emonstration against
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Eastern Scheldt
completely

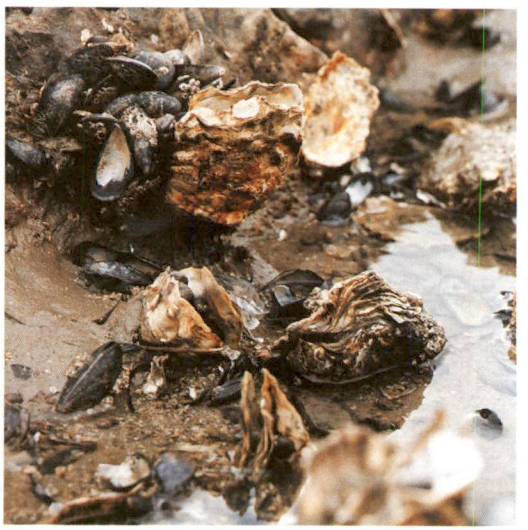
Unique wildlife area

The *Eastern Scheldt* is a rich and unique wildlife area. It is a tidal inlet entirely free of the influence of freshwater rivers and is thus completely saline. The tides generate fast-flowing currents as the water from the North Sea flows into the inlet through channels up to 40 metres deep and two kilometres wide. Sandbars and shallows lie between the channels. In the more inland section of the *Eastern Scheldt* the channels become narrower and shallower. The clean water, with its high salt content and relatively warm temperature, provides unusual conditions.

All kinds of plants and animals that usually live only in more southerly climes can be found in the *Eastern Scheldt*. The ecosystem is highly developed, with many organisms, both common and uncommon. Many valuable species of flora and fauna live on the stone and concrete-clad dykes, for example lichens, snails, sea acorns, sponges, anemones, crabs and starfish. There are dozens of varieties of seaweed, including some rare ones. The *Eastern Scheldt* is a rich store of food, plankton being the most important resource. A million tons of vegetation is produced each year, most of which sinks to the bottom where creatures living on the bed take full advantage of it. In their turn, fish, crustaceans and birds feed on the creatures living on the bed.

The *Eastern Scheldt* is a nursery for fish such as sole, cod, plaice and herring, which breed elsewhere but grow in the tidal inlet, and also a breeding ground for others such as gar, anchovy and pout. There are over 75 different species of fish in the inlet. The *Eastern Scheldt* enjoys an international reputation for its birdlife. Many thousands of birds rest there during migration or come to spend the winter, the summer or the breeding season. There is an abundance of food; the water is pure and rarely freezes in winter. The area is particularly important for water birds. The *Eastern Scheldt* is home to ducks, geese, oystercatchers, plovers and avocets. Many rare plants and animals live on the bed of the inlet. There are also mussels and oysters, which are economically very important.

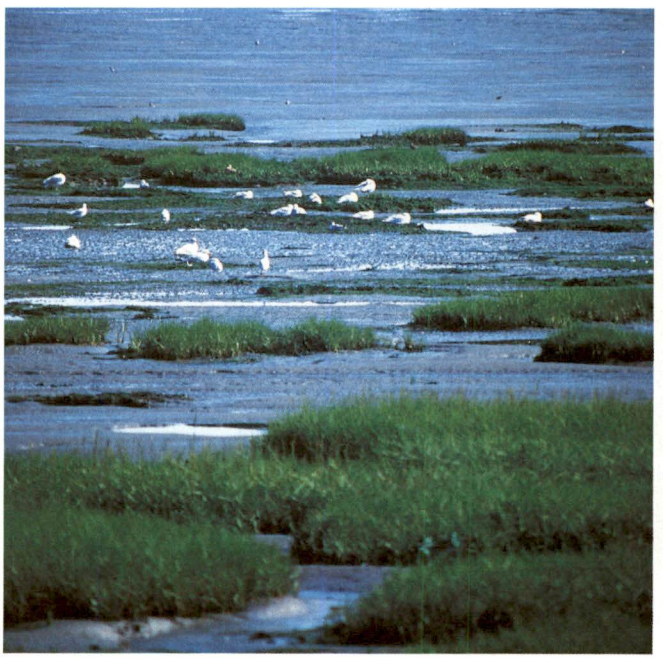




irds on the salt marshes

Sea anemone

Mussels





ıe surface area of salt
rshes and mud flats in
the Eastern Scheldt
uary is reduced by the
storm flood barrier

Along the edges of the *Eastern Scheldt* there are extensive mud flats, which appear to be barren but are in fact teeming with life. Birds in particular take advantage of them. Towards the dykes, where the mud flats have gradually silted up, salt marshes have formed. Saltwater plants grow on the undulating land between the low and high tide marks, which is drained by countless streams. Some sections of the salt marshes are so high that they are submerged only during spring tides. There is a rich and colourful diversity of plants. Glasswort and sea aster are harvested for human consumption. A few of the salt marshes are grazed by sheep. The salt marshes form one of the few natural landscapes remaining in the Netherlands. This too is one of the unique features of the *Eastern Scheldt*.



The half-open dam

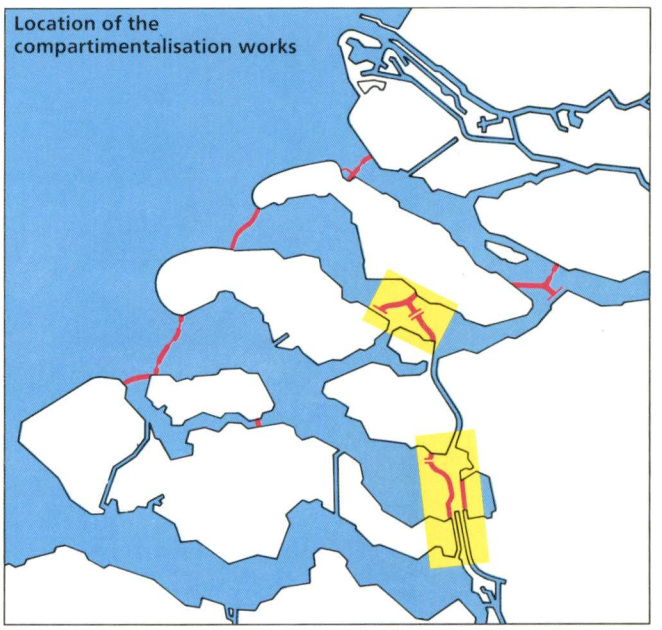
At the end of 1974 Parliament recognised the importance of keeping the *Eastern Scheldt* open and decided to change the plans for the Delta Project. It was not an easy decision to take and there were many opponents to it, so a compromise had to be reached. The plan for a solid dam was abandoned and the engineers were requested to design a reliable method of protection that would also preserve the valuable environment. A design for the half-open dam had to be worked out subject to several conditions: it had to be technically feasible; the additional costs had to be kept to a minimum; and the area around the *Eastern Scheldt* had to be protected from flooding by 1985. The hydraulic engineers were confronted with an entirely new problem, one at the very limits of their technical know-how. As there would no longer be a dam by 1978, the government provided funds to reinforce the weak dykes bordering the inlet. The reinforcement of the dykes considerably improved the safety of the area before the new barrier was completed.



Creation of pitchings on the dike

Pushing back the frontiers

The engineers' problem was to design and construct a reliable, open barrier that would allow the tide to enter the *Eastern Scheldt* each day. Such a project had never been carried out anywhere in the world. The knowledge and experience gained during the implementation of the previous parts of the *Delta Project* were no longer sufficient and there was little time available. Of the various solutions that were proposed the engineers decided on a storm surge barrier across the mouth of the *Eastern Scheldt*. Parliament agreed to the project in mid-1976. The idea behind the storm surge barrier was simple: 65 concrete piers would be placed in the three channels, *Hammen, Schaar van Roggenplaat* and *Roompot,* and firmly anchored with masses of stone, and 62 steel gates that could be raised or lowered would be placed between the piers. Under normal conditions the gates would be raised so that the tidal movement in the inlet would be largely retained, thus preserving the environment. The gates would be lowered during storms when exceptionally high waterlevels were expected, damming the *Eastern Scheldt* from the North Sea and guaranteeing protection from flooding.



As the storm surge barrier would reduce the tide to some extent, it would be necessary to compartmentalise the *Eastern Scheldt* by building dams inland of the barrier. This would reduce the tidal area so as to maintain a sufficient difference in level between high and low tide, namely an average tidal range of 3.2 metres at Yerseke, which was important for the fishing industry. It also guaranteed that the *Scheldt-Rhine* shipping link would be non-tidal, as the Netherlands government had promised Belgium. Compartmentation had the additional advantage of separating salt water from fresh water, which was desirable for efficient environmental conservation and water management. Freshwater peripheral lakes were formed behind the *Philips dam* in the northeast and the *Oester dam* in the southeast. A discharge canal was dredged, leading to the *Western Scheldt,* to control the level and quality of these lakes. For technical and environmental reasons a further dyke was constructed near Bergen op Zoom, which also created a new lake. The final part of the compartmentation works made the *canal through South Beveland* suitable for pushed barges.

Step-by-step construction

The storm surge barrier was constructed step by step. Solid foundations were needed in the sandy bed of the *Eastern Scheldt,* where enormous quantities of sand are continuously being moved, changing the location of sandbars and channels. The bed where the piers were to stand had to be improved. The first operation was to lay block mattresses made of concrete blocks attached to polypropylene sheets to protect the seabed around the area where the piers were to stand. At the site itself, clay strata were were dredged out and replaced with sand covered with a layer of gravel to prevent it from being scoured out during storms.

The barrier is very heavy and the seabed had to be compacted to a depth of 15 metres using a specially designed vessel, the **Mytilus,** to increase its bearing capacity. The **Mytilus** drove four steel tubes into the bed, which were vibrated to force water out from between the grains of sand, eliminating quicksand and thus strengthening the bed. It took three years to compact the bed in this manner. Bed protection, improvement and depth compaction, however, were not enough to ensure that the piers could be placed safely. A foundation had to be constructed on the reinforced bed to prevent the sand from being washed away and to guarantee that the piers would stand evenly.

The Mytilus sea-bed compression vessel



Polypropylene mattresses



Mat factory on the Neeltje Jans artificial island

Polypropylene mattresses filled with graded layers of gravel were used in the foundations. They were made at a factory that had been specifically built for their production. Two kinds of mattresses were made, lower mattresses 200 metres long, 42 metres wide and 36 centimetres thick, and upper mattresses measuring 60x31 metres. 65 mattresses of each kind were needed. As the mattresses were produced in the factory they were rolled onto huge floating drums and then placed on a specially-designed vessel, the **Cardium,** which laid them. The seabed was first levelled using the extra-wide suction nozzle on the bow of the **Cardium** before the vessel rolled the mattresses into position. It sounds a simple operation, but the mattresses had to be laid with extreme precision, which is not so simple in a turbulent tidal inlet. Furthermore, they could only be laid during the short period of slack water between low and high tide, which lasts for just one hour. If a mattress had not been fully unrolled before the tide turned, it would have been destroyed by the force of the ebb tide. Fortunately, this never occurred.

When the mattresses were being laid the **Cardium** was assisted by another specially-designed vessel, the **Jan Heijmans.** This vessel held the ends of the mattresses in place and sealed the seams between them with layers of stone. The piers were placed 45 metres apart, so there was a three-metre seam between them and the 42 metre wide mattresses. Laying the mattresses was a critical stage in the construction of the storm surge barrier: it determined the evenness of the seabed and the strength of the barrier.



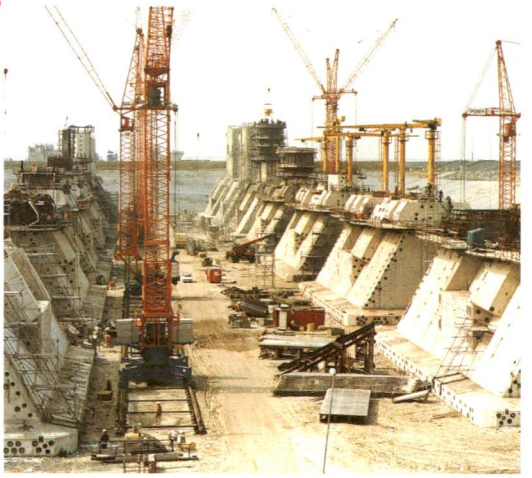
The Cardium mat-laying vessel with the Jan Heijmans stone and asphalt tipper

The Cardium rolls off a mat

The mattresses are filled with graded layers of sand and gravel and act as filters, trapping the sand in place on the seabed but allowing water to flow through them. The mattresses were laid quickly. In some sections a block mattress was laid on top of them to smooth out any unevenness. Another special mattress, a gravel ballast mattress, was finally laid over the seams to prevent the stone from being washed away. The final result was a flat "carpet", more level than most football pitches, across a 200 metre section of the mouth of the *Eastern Scheldt.*

The backbone of the barrier

The 65 enormous piers from the backbone of the barrier. They were constructed in three large construction docks 15 metres deep, which were kept dry by 320 underwater pumps. The piers are colossal structures made of pre-stressed concrete to keep their weight to a minimum. They are 30 to 40 metres tall and have a dry weight of up to 18,000 tons.
The height of the piers depended upon their ultimate position in one of the channels.
A purpose-built factory produced 450,000 m^3 of concrete over four years. The piers were hollow and were filled with sand when they were in position. They are not featureless monoliths but contain many notches and indentations where the other concrete components and the steel gates are attached. It took just under one and a half years to construct each pier. As all the piers had to be completed in only four years, they were produced in staggered batches with work beginning on a new pier every two weeks. At the peak of activity 30 piers were being constructed simultaneously.



erial construction of pillars

ars in a building dock

When all the piers in a construction dock were completed, the dock was flooded and the encircling dyke was opened so that they could be transported to one of the channels in the mouth of the *Eastern Scheldt*. This operation too required unusual vessels. The **Ostrea** was designed and built to lift the piers in the construction dock, transport them to the channels and then place them with great precision on the mattresses. The **Macoma** was specially built to moor the **Ostrea** while it was placing the piers and to clean the site immediately beforehand. The piers were positioned with pin-point accuracy at slack water using very sophisticated measuring equipment. It took a year to place them all.

Work on the piers was far from over once they had been placed. They still needed to be grouted, which involved filling the space between the foot of the pier and the foundation mattress with grout, a mixture of sand, cement and water, to achieve a perfect bond with the mattress. Once this operation was completed, the lower sections of the piers were filled with sand to increase their stability. They were then covered with a layer of concrete to protect them from damage. The foot of the piers was protected by stone/asphalt bags, each weighing 30 to 40 tons. These were necessary as each pier had to be embedded in a sill made of dumped stone.

The Ostrea crane vessel and the Macoma mooring and cleansing pontoon shortly after a pillar has been installed

The turn of the tide, the right time to install the pillars





Ten-ton stones

The sill increased the piers' stability and also helped dam the mouth of the Eastern Scheldt. The ultimate intention was that only that part of the barrier which could be closed by gates was to remain open. The sill was constructed of graded layers of stone. Lighter stones were placed at the bottom and huge blocks weighing as much as ten tons (10,000 kilogrammes) were placed on top. These blocks have to be so heavy in order to withstand the powerful currents that would build up if one of the gates refused to close during a storm. The largest stones could not be dropped into position as the risk of their damaging the piers was too great. The **Trias** was therefore designed to lay the top layer of stone. This vessel was equipped with a large crane with a long extendable arm that was used to place the heavy stones accurately. Five million tons of stone were used in the construction of the sill. It had to be imported over a period of four years from Germany, Finland, Sweden and Belgium as it was not available in the Netherlands.



Stone deposits at the dge of the storm flood barrier

The Trias top-layer ipping vessel in action

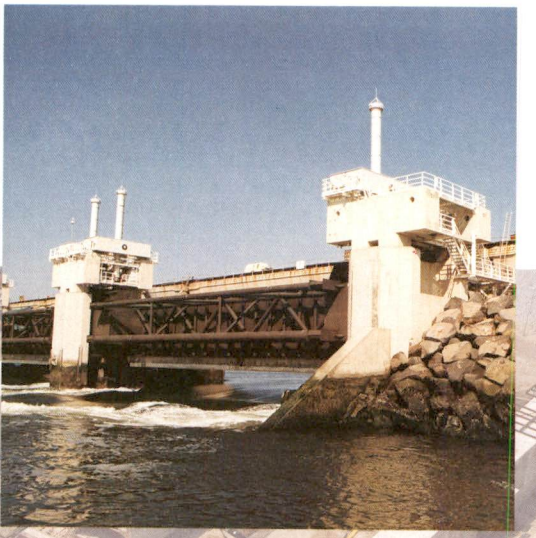
e Taklift IV crane vessel vith a road bridge box girder in its hoist

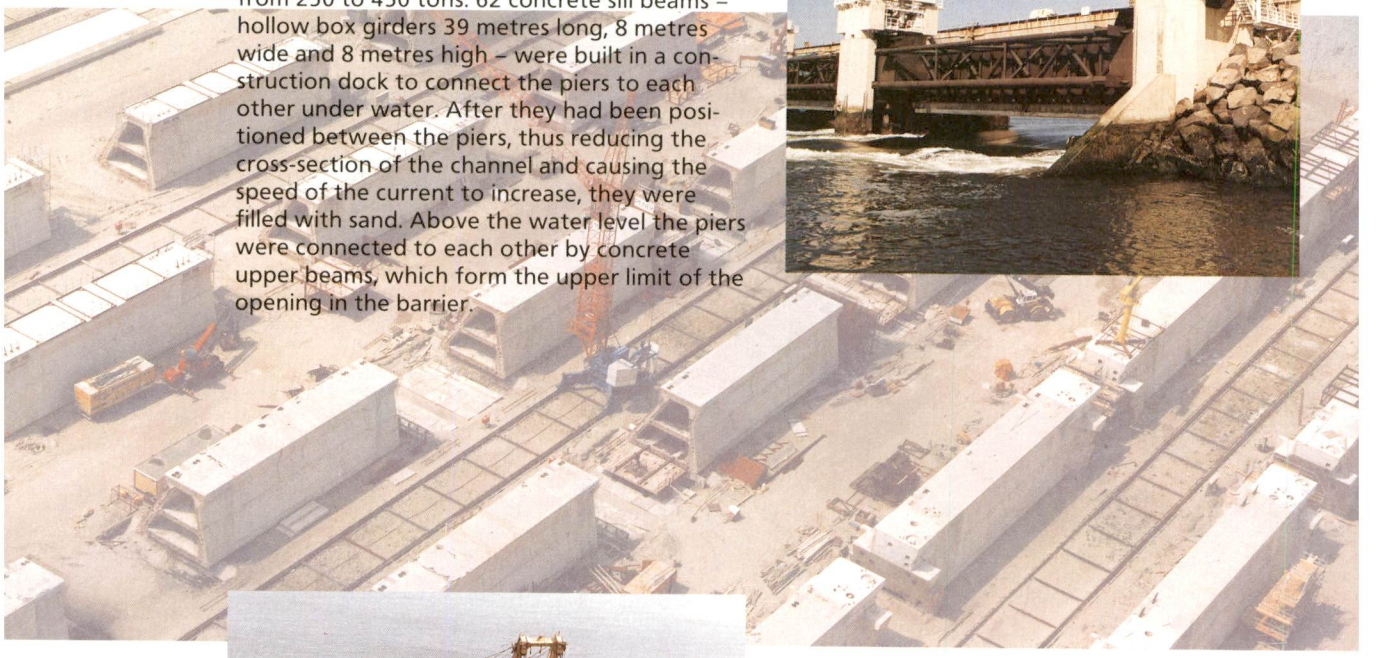


When the work on the foundations, the piers and the underwater sill was finished, a large part of the battle had been won, although there was still a lot of work to be done to complete the barrier. In order of assembly, service ducts, pier capping units, gates, sill beams and upper beams had to be installed. These are all indispensable components for the efficient operation of the storm surge barrier. The concrete service duct, each section of which was 45 metres long, was placed on the piers by the floating crane **Taklift 4.** A major road now runs over the top of the service duct, while part of the space inside it has been used to house the operating and control equipment for the gates.

Ever increasing currents

The capping units were made of prestressed concrete and were installed to increase the height of the piers to accommodate the gate structure. The height of the 124 upper members varies from 4.3 to 10 metres and their weight from 250 to 450 tons. 62 concrete sill beams – hollow box girders 39 metres long, 8 metres wide and 8 metres high – were built in a construction dock to connect the piers to each other under water. After they had been positioned between the piers, thus reducing the cross-section of the channel and causing the speed of the current to increase, they were filled with sand. Above the water level the piers were connected to each other by concrete upper beams, which form the upper limit of the opening in the barrier.







Between the dam and the pier lies a quarry stone dam

ıstallation of sill beams in trench

'he Taklift hangs a lock hatch in place

Positioning of lock ıtches is precision work



The steel gates were designed to hold back the waters of the North Sea during storms. Their height varies from 5.9 to 11.9 metres depending upon their position in the barrier. The largest gate, weighing 480 tons, is located in the deepest channel, the Roompot. The gates were installed between the piers using the **Taklift 4**. When the gates are raised the *Eastern Scheldt* is open and sufficient water can flow into it to ensure a tidal range of 3.2 metres at Yerseke, the centre of the shellfish industry. That is just over three-quarters of the original tidal range and enough to preserve the existing wildlife and the fishing industry.

Gates closed

The gates consist of plating and tubular steel girders. The plating, which is on the Eastern Scheldt side, needs to be just one centimetre thick to withstand storms. The gates have been designed to resist the loads caused by different water levels on either side and can be raised or lowered in fast flowing water under adverse weather conditions. Each gate is opened or closed with the aid of two hydraulic cylinders, varying in length from 21.8 to 34.5 metres. The gates can be moved at a speed of three millimetres per second, which means that it takes an hour to open or close the largest gate.

The storm surge barrier is operated from the **Tops-huis,** the central control building standing high above the North Sea at some distance from the barrier. On average the barrier has to be closed once a year due to extremely high water levels. The **Tops-huis** also accommodates the **Delta Expo,** a permanent exhibition on 2,000 years of hydraulic engineering. On the southern part of the Neeltje Jans construction island the Roompot lock was built because ships can no longer pass freely through the mouth of the *Eastern Scheldt.* A road has been built on a viaduct above the barrier.

On 4 October 1986 Her Majesty Queen Beatrix officially declared the storm surge barrier in the Eastern Scheldt open.



'he Ir. J.W. Tops-huis, ıe storm flood barrier service building



ɛ storm flood barrier is ɔmpletely computer-controlled

ıeen Beatrix opens the :astern Scheldt storm ood barrier. Standing vith her are Transport and Public Works linister Dr. Neelie Smit (left) and J. van Dixhoorn, ıe Director General of Public Works



Other uses

The storm surge barrier was constructed to provide greater protection from the sea and to preserve the unique and valuable environment of the *Eastern Scheldt.* This has largely determined how and when the barrier is operated, and the steel gates will be kept open whenever possible. In principle the barrier is closed only when it is predicted that the high water level will exceed 3.25 metres above AOD. A danger level has also been decided upon, as the sea is often unpredictable and the water level can rise suddenly. If the water rises above the danger level the gates will close automatically. A warning system has been developed that makes use of long-range weather forecasts.

Opening or closing the barrier will affect the safety of the flood defences along the *Eastern Scheldt* (strong dykes are still necessary) and also the environment, the fishing industry, water management and shipping. When the barrier is operated, therefore, as much account as possible will be taken of conditions in the *Eastern Scheldt.*

The barrier can of course be operated for other purposes in addition to flood prevention. Since this could endanger the environment, however, it has been decided that when the water level is not dangerously high the gates will be closed only to prevent oil or chemical pollution from entering the *Eastern Scheldt,* to limit the effects of dyke collapse and to prevent drift ice damaging the dykes. The storm surge barrier was also closed during the construction of the compartmentation dams in 1986 and 1987 to moderate the effect of the tide. Reducing the tidal current made it possible to construct the *Oester* and *Philips* dams using sand.

New peripheral lakes

The compartmentation dams necessitated by the building of the barrier were constructed on the border between the provinces of Zeeland and North Brabant. Interconnected peripheral lakes formed as a result of the construction of the *Oester* and *Philips* dams. From north to south these lakes are the *Krammer/Volkerak,* the *Zoommeer* and the *Markiezaatsmeer.* A sophisticated salt/freshwater separation system has been built into the *Krammer* lock complex to prevent the fresh water of the lakes mixing with the salt water of the *Eastern Scheldt.* Water can be discharged from the *Zoommeer* via the *Bath canal* into the *Western Scheldt* so that the level of the peripheral lakes is kept constant. The *Oester* and *Philips* dams were constructed using sand and are the largest sand dams in the world to have been constructed in flowing water.



Philips Dam





9 The Philips dam 1987

The Philips dam was constructed between Sint Philipsland and the Grevelingen dam. A large lock complex, the Krammer locks, was built on a construction island in the middle of the dam. Two locks were built for commercial shipping and are suitable for four-barge push-tows. A separate lock was built for pleasure craft. A salt/freshwater separation system was built into the lock complex to prevent large quantities of salt water entering the freshwater Krammer/Volkerak whenever a ship is locked through from the Eastern Scheldt, and conversely to prevent dilution of the Eastern Scheldt with fresh water. It works on the principle that salt water is denser than fresh water. During the lockage of ships to the Krammer/Volkerak the salt water of the Eastern Scheldt is replaced with fresh water, and the procedure is reversed for ships travelling in the opposite direction. This system has also been used in the Kreekrak locks to prevent the brackish and polluted water from the industrial area around Antwerp entering the Zoommeer.



Markiezaatskade quay

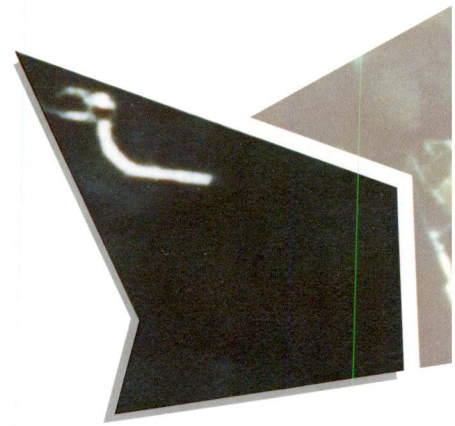
10
The Markiezaat dyke
1983

A special dyke had to be constructed to prevent strong currents building up during the construction of the Oester dam, which would have caused problems for shipping and weakened the banks. This dyke was built along the edge of the submerged former marquisate of Bergen op Zoom; hence its name, the Markiezaat dyke. A serious set-back occurred during the construction of this dyke, which extends five kilometres between the Kreekrak locks and the Molenplaat near Bergen op Zoom. 1982 it had been virtually completed and only the finishing work needed to be done when a storm surge 3.7 metres above AOD breached the dyke. The dyke was finally completed a year later. A freshwater lake has formed behind the Markiezaat dyke, most of which will remain a wildlife area.



11
The Oester dam
1986

The Oester dam was built between Tholen and South Beveland. Extending nearly 11 kilometres, it is the longest of all the dams in the Delta. It separates the Scheldt-Rhine shipping route from the Eastern Scheldt, so that this important link is now non-tidal. The dam lies close to the Scheldt-Rhine link in the most easterly section of the inlet and therefore the majority of the Eastern Scheldt remains tidal. A lock, the Bergsche Diep lock, has been built in the dam near Tholen for pleasure craft and fishing boats moving between the Zoommeer and the Eastern Scheldt. The dam was built in an area where man had often done battle with the sea in the past. The composition of the bed was so erratic that it had to be improved in many places.





'he Oester Dam with the Bergse Diep lock

A simple technique

A sluice has been built in the *Grevelingen dam* just south of the point where it meets the *Philips dam.* It uses a simple principle: that of the siphon. It does not need expensive gates. The siphon allows water to flow between the *Grevelingenmeer* and the *Eastern Scheldt.* The siphon and the discharge sluice in the *Brouwers dam* enable the *Grevelingenmeer* to be flushed with water to keep its salt content at an acceptable level.

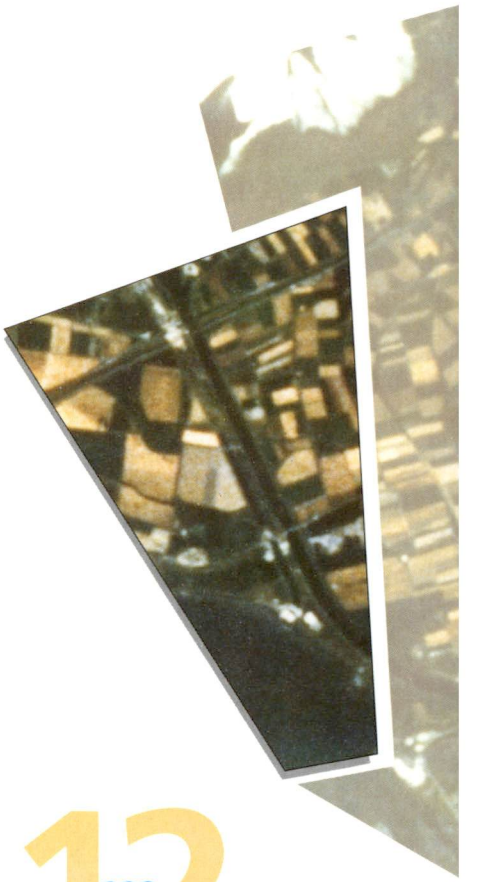
Water from the land inland of the compartmentation dams drains into the peripheral lakes and the level and quality of these lakes have to be controlled. Inlet sluices have been constructed in the *Volkerak dam* and when necessary water from the Rhine and Maas can enter the peripheral lakes via the *Hollandsch Diep.* As there are often toxins in the rivers, though, the river water is only rarely allowed to enter the peripheral lakes; otherwise the beds of the *Krammer/volkerak* and the *Zoommeer* would be covered with a layer of highly polluted alluvium.



Bathse drainage sluice



The mouth of the canal running through Zuid Beveland at Hansweert



12 The Bath Discharge Canal 1987

The eight-kilometre Bath discharge canal has been excavated across the neck of South Beveland to discharge excess water from the rivers and polders. It runs parallel to the Scheldt-Rhine link and can discharge 8.5 million^3 of water per day. At the outlet in the Western Scheldt there is a sluice made of concrete tunnels that forms part of the sea wall. The sluice gates are closed when the water level in the Western Scheldt is high, thus preventing salt water from the Western Scheldt entering the Zoommeer. The existing canal running through South Beveland was also improved as part of the compartmentation works. New locks were built at Hansweert, the canal was widened and a lock-free mouth was created near Wemeldinge.

The Delta project completed

The bold programme of hydraulic engineering works in the Delta produced enormous changes affecting people, animals, plants and the landscape. Dams, locks and roads were constructed and new lakes and residential and recreational areas were created. Sweeping changes have occurred in the age-old rhythm of ebb and flow. The environment has altered in many places and in many ways. In addition to protecting the southeast Netherlands from flooding and producing economic benefits, the implementation of the Delta Project increasingly took account of ecological requirements. A delta is a very rich and varied system of plant and animal communities: an ecosystem that is also economically important and very sensitive to human intervention.

The Netherlands was willing to spend a lot of money on the Delta Project. The cost of ensuring protection from flooding, radically improving the communications network, distributing the scarce supplies of fresh water more efficiently and preserving the unique ecosystem came to Fl. 12,000 m. The work in the *Eastern Scheldt* was the most expensive part of the *Delta Project,* costing Fl. 8,000 m.

During the official opening ceremony of the storm surge barrier, Queen Beatrix declared the Delta Project completed. The work in the southwest Netherlands may be over, but there is still a lot of work for the hydraulic engineers. Shallows and sandbars are developing in front of the dams and headlands, and gradually becoming higher, promoting the formation of new channels. This area can offer new opportunities to the fishing industry and the environment. Plans are therefore already under consideration in connection with the *Delta Project* for the future of this area. The steady rise of the sea level also indicates that the protection of the Netherlands against the sea will remain a permanent struggle. Dutch hydraulic engineers believe that the knowledge and expertise they gained in the thirty years it took to complete the Delta Project should also benefit other countries in addition to the Netherlands.



The last lock hatch is put in place

The storm flood barrier is complete



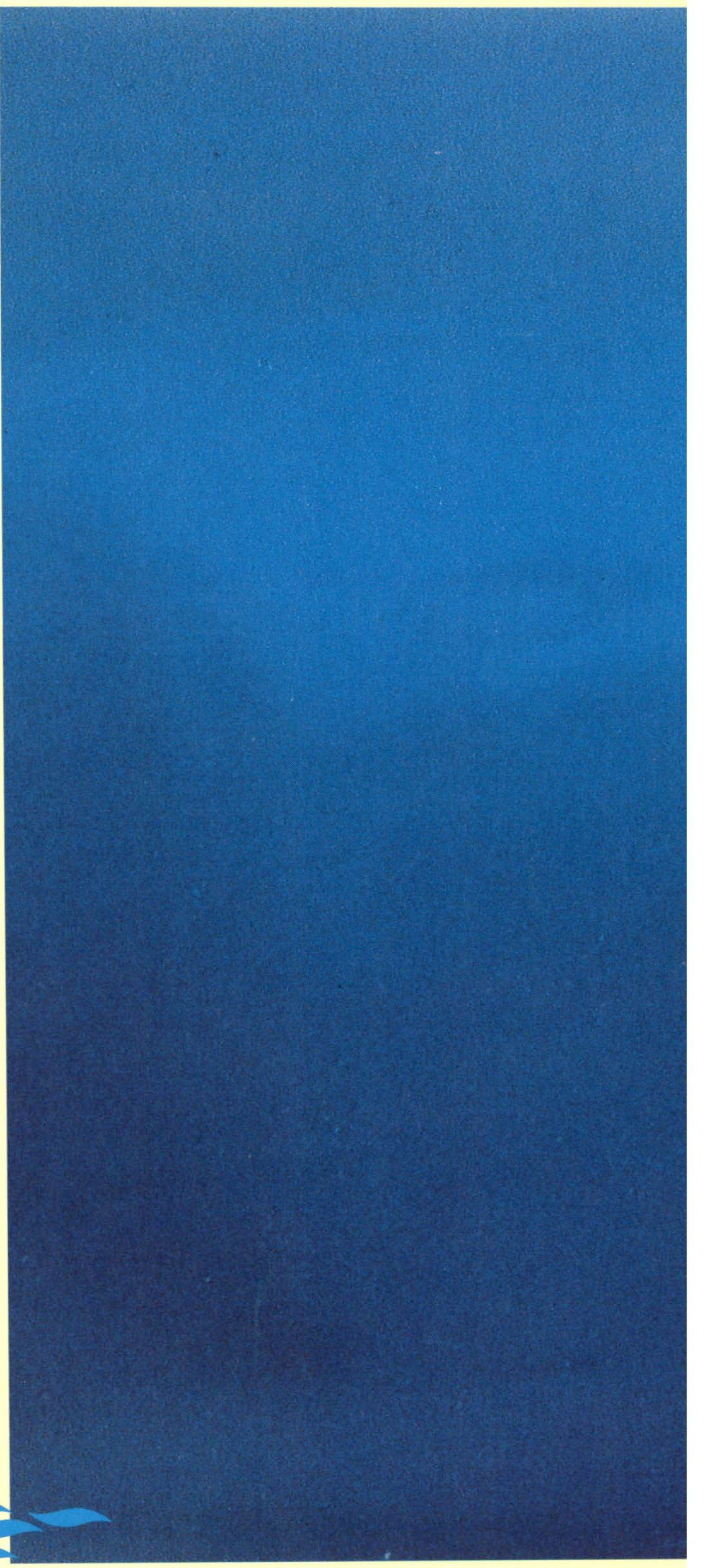
Colophon

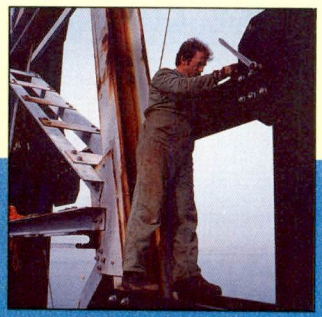
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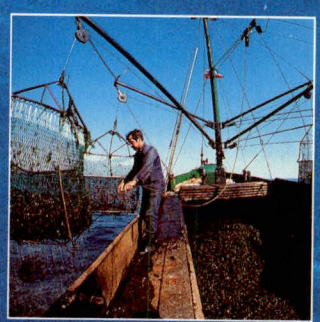






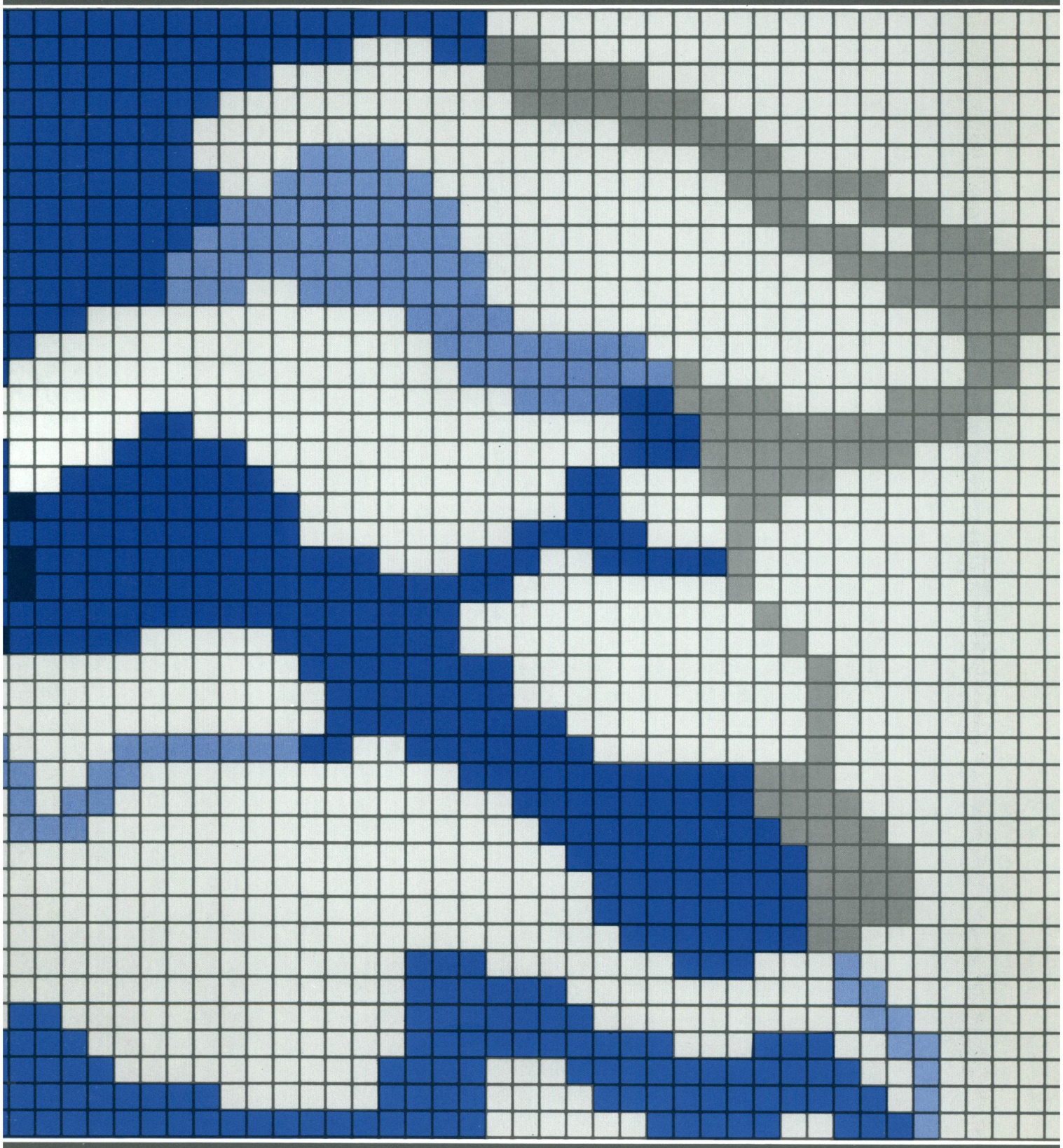

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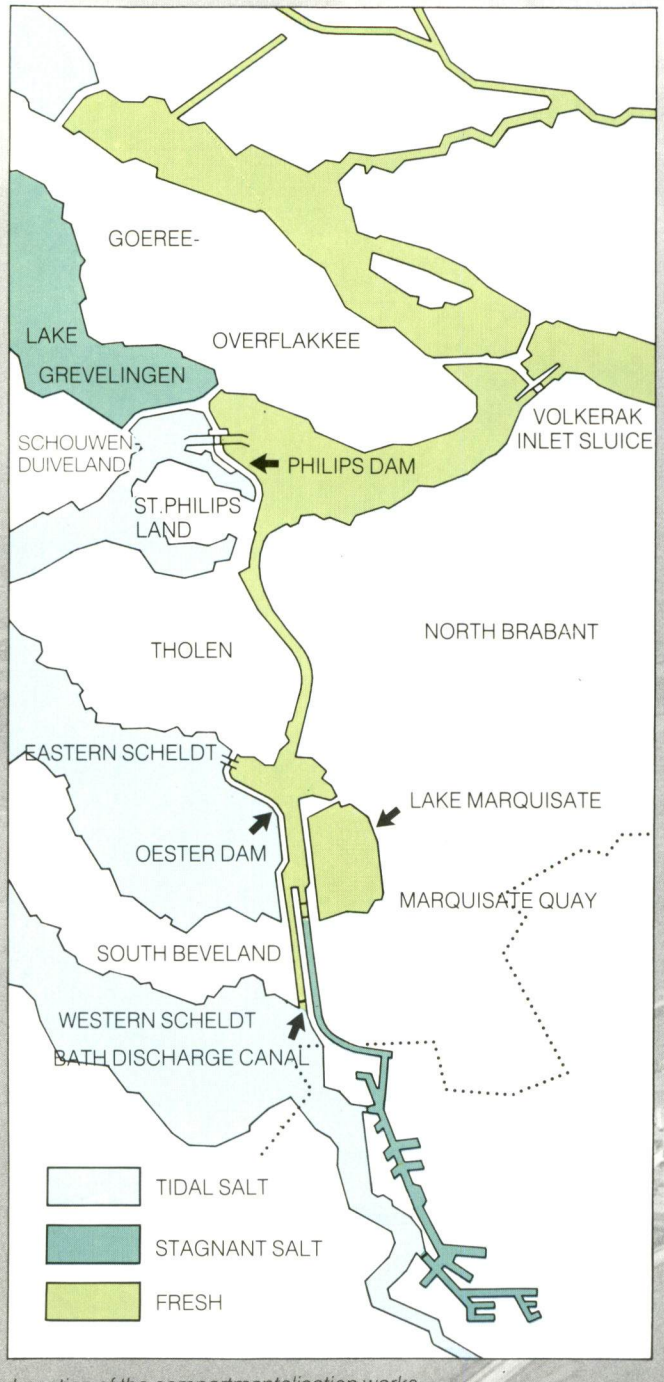




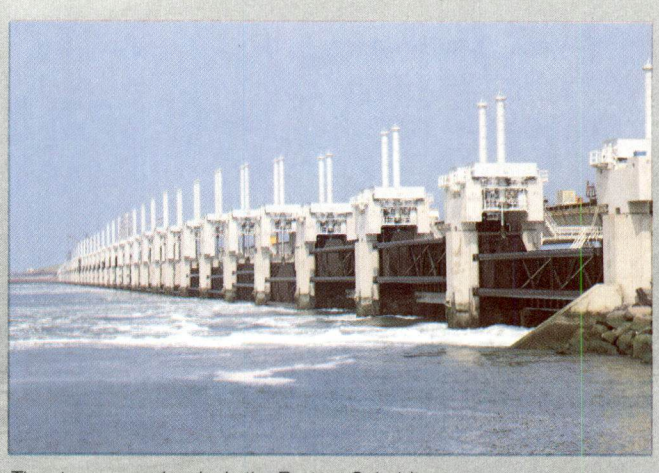
The compartmentalisation works in the Eastern Scheldt

for the benefit of the natural environment, water management and shipping





Location of the compartmentalisation works



The storm surge barrier in the Eastern Scheldt

The construction island in the Krammer with locks, approach harbours and water reservoirs.

The compartmentalisation works in the eastern scheldt for the benefit of the natural environment, water management and shipping

The original scenario for the Delta Project envisaged the damming of all the estuaries, distributaries and waterways open to the sea in the south-west of the Netherlands with the exception of the New Waterway and the Western Scheldt, which would remain open for shipping. The dams were to protect the hinterland from storm surges such as the one which took such a heavy toll of lives and property in 1953. The Eastern Scheldt was also to be closed off by a dam 9 kilometres in length, creating a freshwater lake which would have incorporated the Krammer and the Volkerak. But in the early seventies public demand for the conservation of the existing natural environment in the Eastern Scheldt was so great that the government decided on a change of plan. A storm surge barrier which can be closed as occasion demands has now been constructed. Under normal conditions, the 62 steel gates remain open to permit virtually normal tidal movement, but if storms give rise to the threat of excessively high water levels the gates can be closed until the danger passes. In this way the valuable natural environment in the Eastern Scheldt area can be conserved, fishing activities can continue unhindered and, at the same time, the population of this part of the Netherlands is protected from the hazards associated with extreme weather conditions.
The decision to build the storm surge barrier also embraced the construction of two compartmentalisation dams in the eastern section of the estuary, the Philips dam in the north-east, and the Oester dam in the south-east, enclosing a freshwater peripheral lake. A discharge canal linking up with the Western Scheldt was dug with a view to maintaining the quality of the water in this lake as well as controlling water levels. As part of the compartmentalisation scheme the existing canal through South Beveland is being adapted for pushed barge traffic.

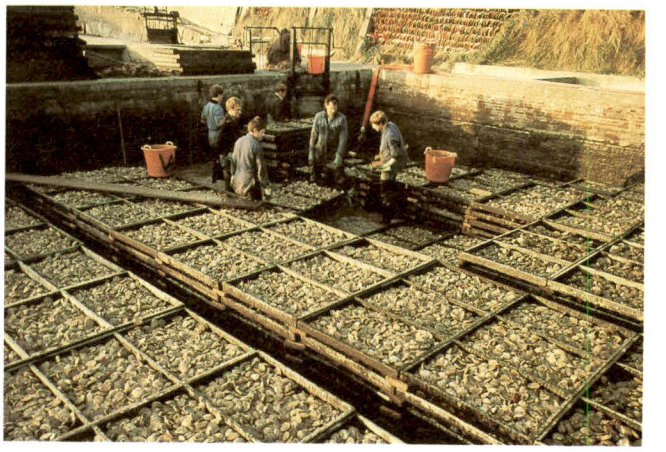




A resting place and feeding area for birds



Underwater life



An oyster farm near Yerseke

Fixed arch bridge over the Scheldt-Rhine link



Tidal movement in the Eastern Scheldt. Above: low water
Below: high tide six hours later





Why compartmentalisation?

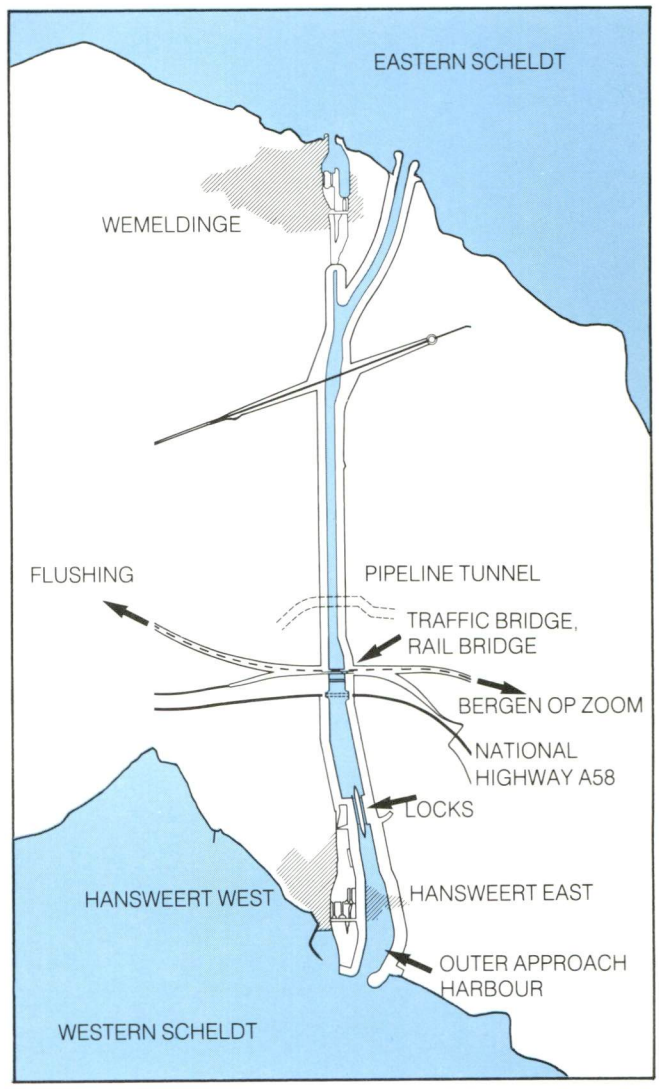
The compartmentalisation dams are necessary for the following reasons:

a) to reduce the tidal area in the Eastern Scheldt
b) to make the Scheldt-Rhine link non-tidal
c) to create a freshwater buffer lake between the salt seawater section of the Eastern Scheldt and the freshwater complex in the western part of the province of Brabant and the Hollands Diep.

a) To keep the cost of the storm surge barrier within certain limits the total area of the opening had to be restricted to approximetaly 14,000 m^2, as a consequence of which the volume of tidal flow has been reduced. Both the reduction in the difference between low and high water and the reduced velocity of the water passing through the barrier is detrimental to flora and fauna and to the important mussel and oyster industries. However, the construction of the Philips andd Oester dams has reduced the tidal area so that the reduction in the tidal range is restricted to about 25%. A minimum range of 2.70 m at Yerseke can thus be achieved.

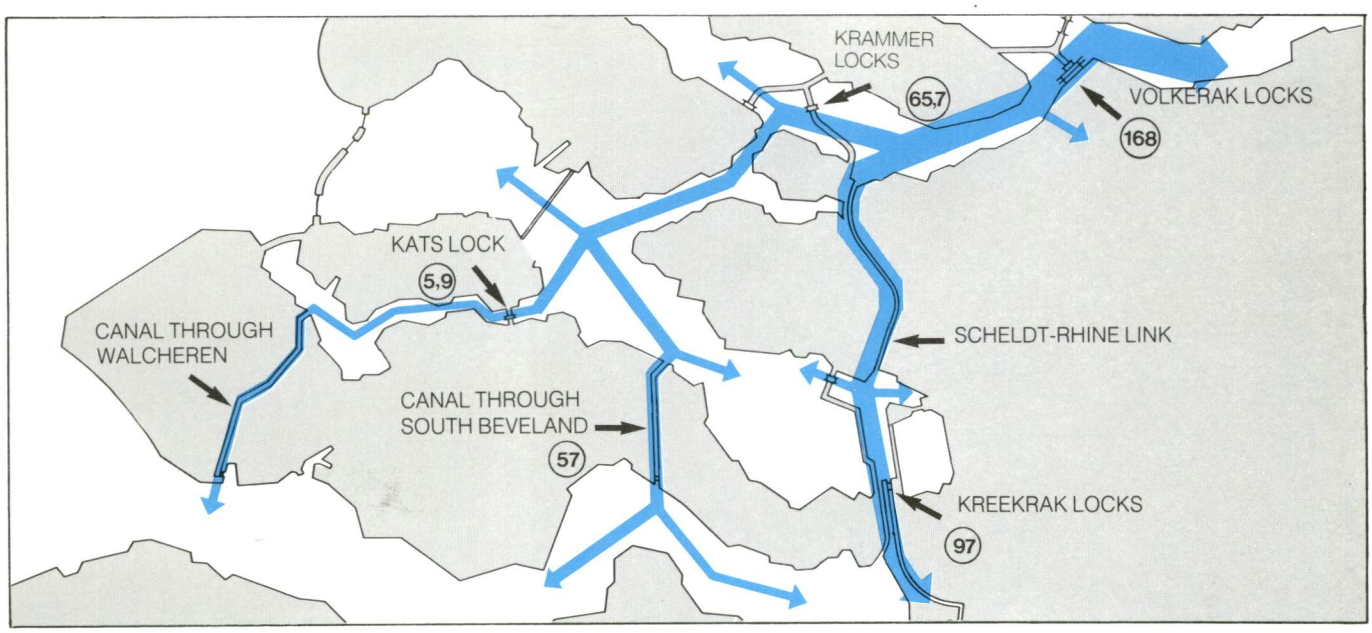
b) In 1963 Belgium and the Netherlands concluded a treaty on the shipping link between the Scheldt and the Rhine which assured that the shipping channel would be non-tidal. At the design stage of the Scheldt-Rhine link, opened in 1975, provision was made for a fixed water level which would be attained when the Eastern Schelde was completely closed off (originally scheduled for 1978). If tidal movement were retained the fixed bridges would not be high enough to allow sufficient clearance for shipping at high water and at low water the canal would not be deep enough. The two compartmentalisation dams thus ensure that the international inland shipping channels are also kept free of tidal movement.

c) Apart from this a freshwater lake is necessary: it is important to both water management and environmental management that the salt water of the Eastern Scheldt should be separated from the fresh water of the peripheral lake to the east of the dams. This prevents both salinization of the hinterland and desalinization of the Eastern Scheldt.
In order to control the water level and the quality of the peripheral lake, it was decided to construct a discharge canal with a discharge sluice into the Western Scheldt.



Adaptation of the canal through South Beveland

Shipping routes in the southern Delta area. Projected cargo figures for 1990 in millions of tonnes capacity





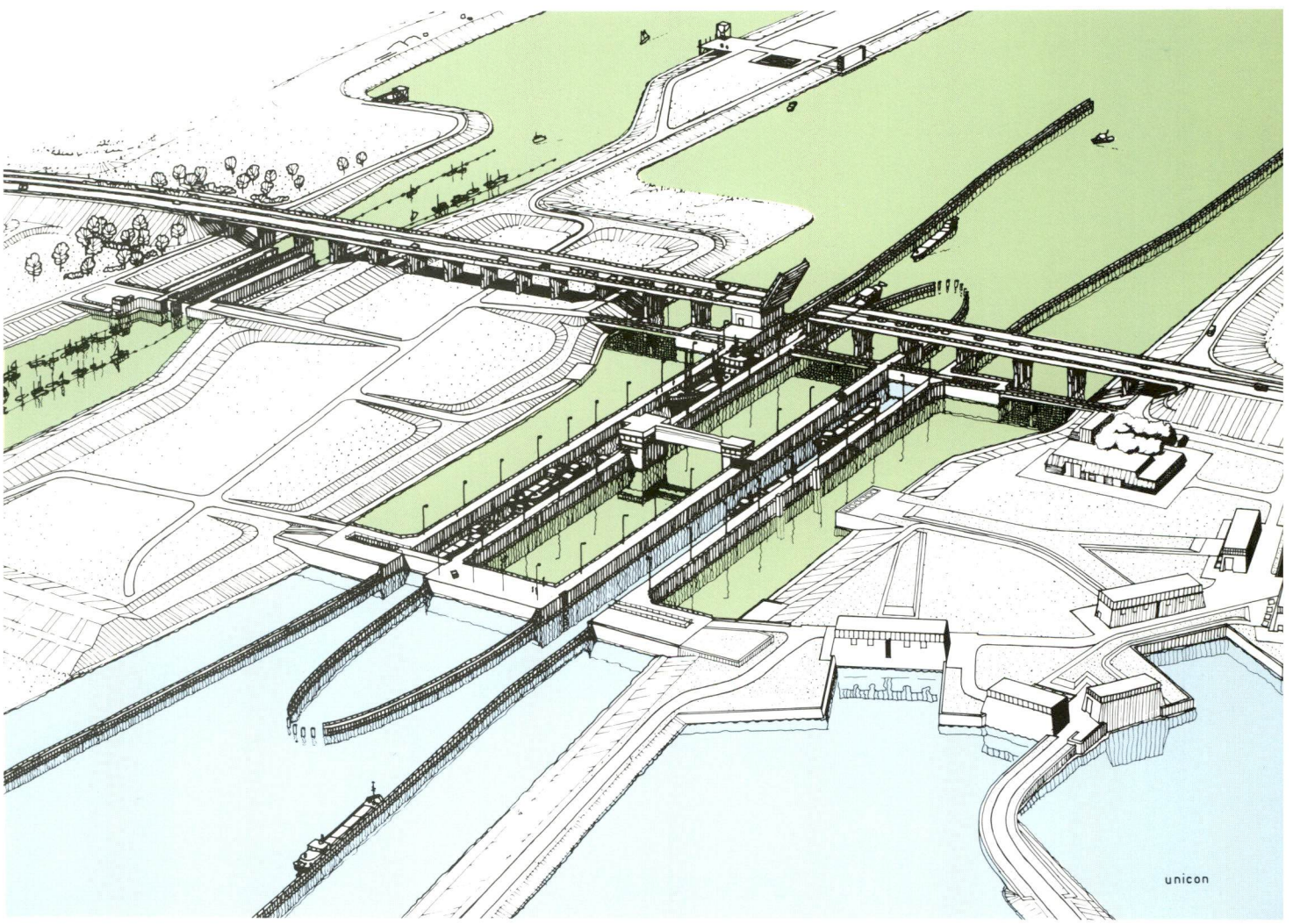
The Philips dam lock complex

The extra dams built across the navigation route between Zeeland and the major rivers are an obstacle to shipping, so locks had to be built. An artificial island was built in the Krammer with a lock complex and approach harbours for inland shipping and pleasure craft. There are two locks 280 metres long and 24 metres wide for 4-barge push-tow units. In addition there are two pleasure craft measuring 9 m x 75 m. The sill depth of the push-tow locks is 6.25 metres below A.O.D. (A.O.D. = Amsterdam Ordnance Datum, mean sea level as defined for Amsterdam). Space has been reserved for a future third push-tow lock if this should be necessary. Since this is a busy shipping route it was decided to build separate locks and approach harbours for commercial and pleasure craft traffic. The lock complex has been furnished with a fresh/saltwater separation system to prevent large quantities of salt water from the Eastern Scheldt entering the freshwater peripheral lake during locking and, vice versa, to ensure that the Eastern Scheldt is kept relatively free of fresh water. This ingenious system makes use of the fact that salt water is heavier than fresh water, together with a system of storage reservoirs and pumps for removing either the fresh or salt water from the locks and returning it to its original location.

For the construction of the lock complex an island with an area of 96 ha. was built in 1977 and 1978 in a shallow section between the Krammer and Slaak channels. A 700 m temporary bridge was built out to the island to facilitate construction work. After the construction of a surrounding dike and a pumping station the 18 ha. construction site was pumped dry in 7 weeks in 1979, after which further excavation work was carried out to a depth of 15 metres below A.O.D. In order to pump the site dry 152 wells had to be dug to a depth of 47 metres below A.O.D.; the total capacity of the pumps was 6000 m3 per hour. Before work could begin the subsoil at the bottom of the site was reinforced to such an extent that pile-driving was not necessary. The lock complex was the largest concrete construction work ever contracted out by the Public Works Department (Rijkswaterstaat) as a single commission. Each of the two push-tow locks has a reinforced concrete lock chamber with the floor 3 metres thick and a perforated upper floor. In the centre of each chamber, between the two floors, there are culverts to supply and discharge water and these are connected to the two storage reservoirs and also to the adjacent section of the Eastern Scheldt, the Slaak channel. The locks are surrounded on three sides by the fresh water the peripheral lake known as the Zoommeer; on the fourth side they are separated from the salt water of the Eastern Scheldt by retaining walls built into the piers on the seaward side of the lock.

Left: the Kreekrak locks in the Scheldt-Rhine link.

Below: the Krammer locks in the Philips dam.





The first phase of the construction island in the Krammer: building the dam to contain the construction harbour.

The temporary bridge giving access to the construction island.





The Krammer locks before and after the flooding of the construction site.

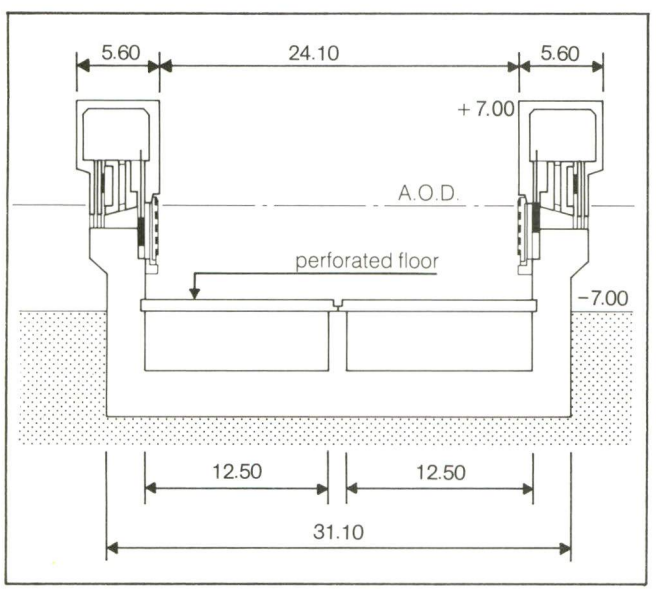


The fresh/saltwater separation system

The system works on the principle that when the lock is closed the fresh water in the lock chamber is replaced by salt water, or vice versa, depending on whether the vessel is entering or leaving the peripheral lake. Obviously it cannot come into operation until the Philips dam has been completed and the salt and fresh water have been separated leaving the Zoommeer. The system includes two storage reservoirs, one of 45 ha. with a lower water level and one of 40 ha. with a higher water level. The lock chambers are connected to these reservoirs and to the Slaak channel in the Eastern Scheldt by a system of culverts and sluices.

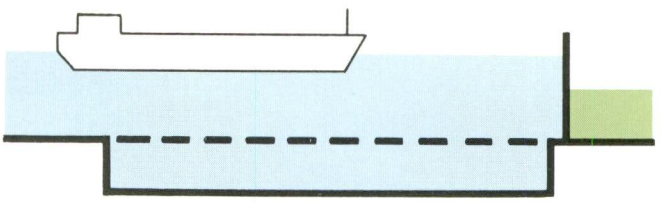
The lock chamber walls contain openings which can be sealed by means of sliding panels. When open they admit fresh water from the surrounding Zoommeer. This is made possible by simultaneously releasing a similar quantity of salt water through the perforated floor and via the system of outlet sluices into the lower reservoir. The salt water in the chamber is thus replaced by fresh water entering above it. If the lock chamber has to be filled with salt water, i.e. if a ship is proceeding from the Zoommeer to the Eastern Scheldt, the salt water is allowed to flow via the inlets, culverts and perforated floor from the higher reservoir into the lower section of the lock chamber. Since salt water is heavier than fresh water there is little chance of the two mixing. The salt water forces the fresh water upwards so that it flows through the openings in the chamber walls into the freshwater lake. In this way the chamber is supplied with salt water from below. At certain times the level of the water in the Eastern Scheldt is sufficient to perform this function and the reservoirs are not required.

In order to connect each of the locks with each discharge sluice a whole network of culverts was created. The total width of the six culverts is 50 metres, while the diameter of each of these huge pipes is approximately the same as that of a railway tunnel.

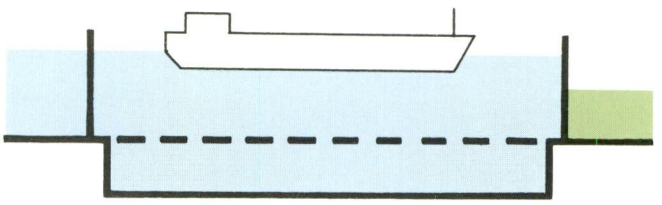


Cross-section of a push-tow lock

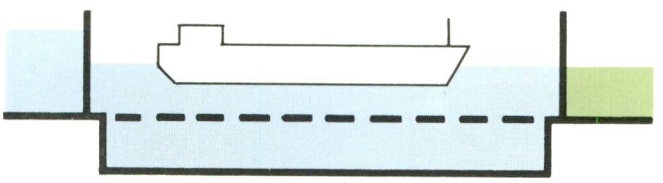
EASTERN SCHELDT THE ZOOMMEER PERIPHERAL LAKE



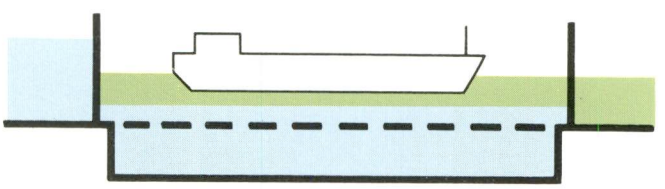
1. ENTRY FROM EASTERN SCHELDT (SALT WATER)



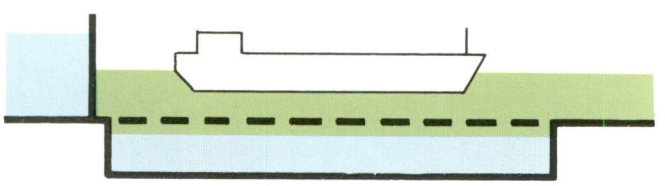
2. SEAWARD GATE CLOSED



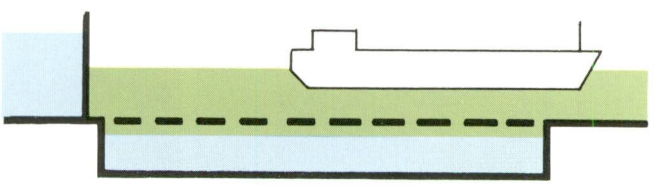
3. LEVELLING OF SALT WATER WITH FRESHWATER LAKE



4. REPLACEMENT OF SALT WATER WITH FRESH WATER



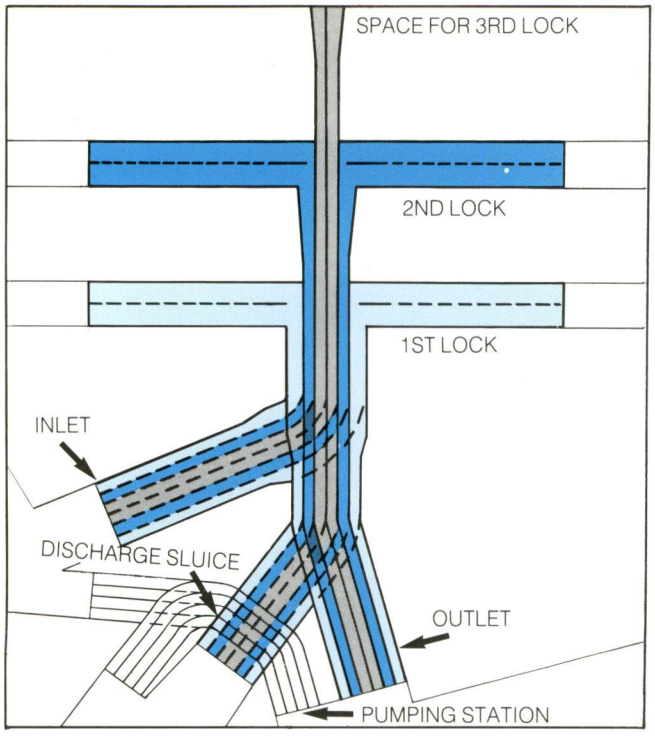
5. LANDWARD GATE OPENED



6. ENTRY INTO VOLKERAK (FRESH WATER)
Locking cycle

Far right: construction of the pumping station in the Philips dam



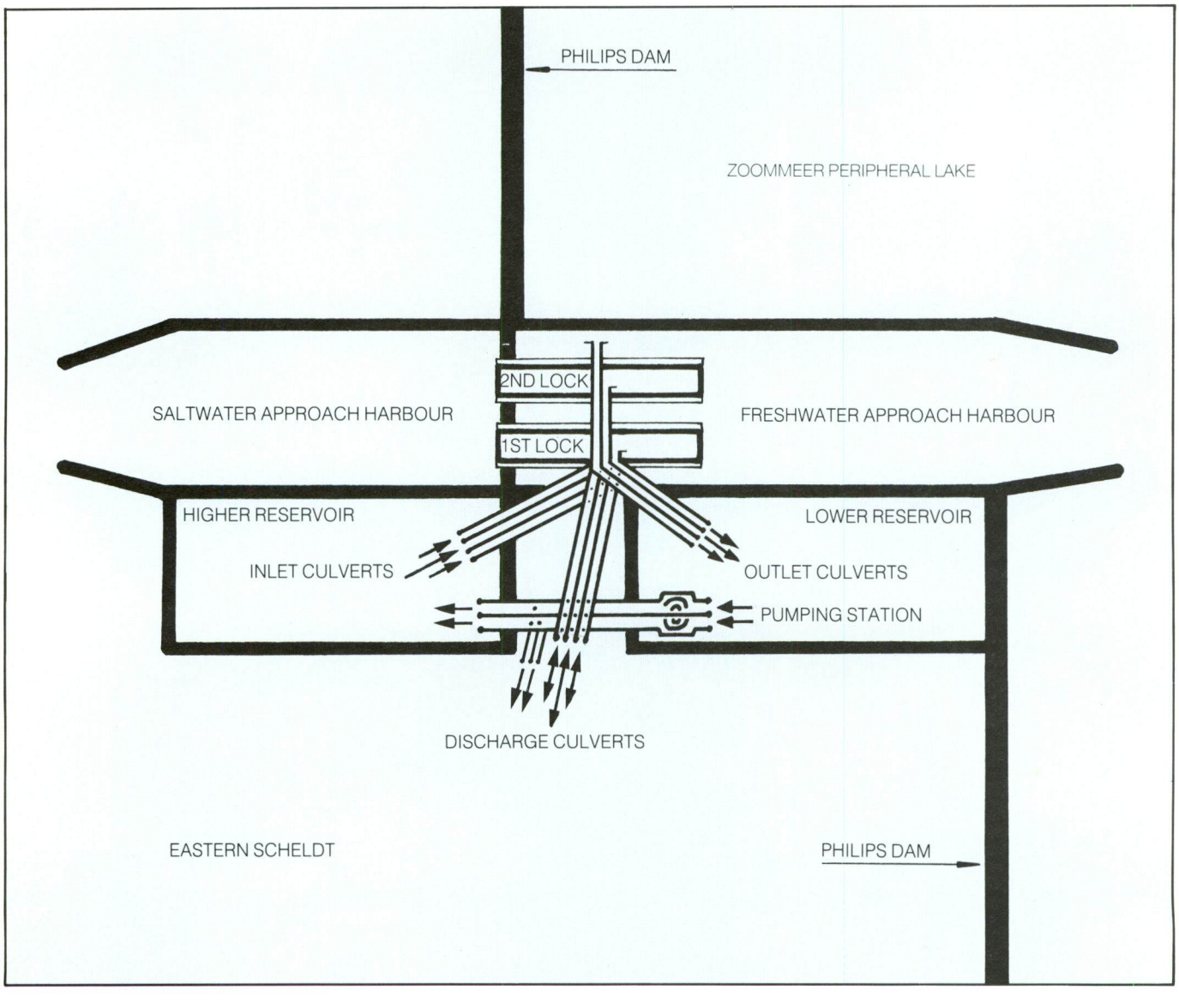


The system of culverts in the push-tow locks

The water in the above network flows in accordance with the interconnected vessels principle. If only pumps were used to effect the exchange if waters between the chambers, ie, if culverts or reservoirs were not used, this would result in higher energy costs. The water in the reservoirs must be kept at the desired level. This can be done by pumping water out of the lower reservoir into the Eastern Scheldt or into the higher reservoir. For this purpose a pumping station was built with four adjustable-screw centrifugal pumps each of which can move 11.5 m3 per second. The capacity required for two locks is approximately 20 m3/sec. At high tide in the Eastern Scheldt the higher reservoir can be filled without the use of pumps simply by lowering a section of the surrounding ring dike.

Right: general view of the site of the pumping station and system of culverts for the locks in the Philips dam.

Diagram of the inlet, outlet and discharge sluices in the push-tow locks of the Philips dam





Wall openings and perforated floor





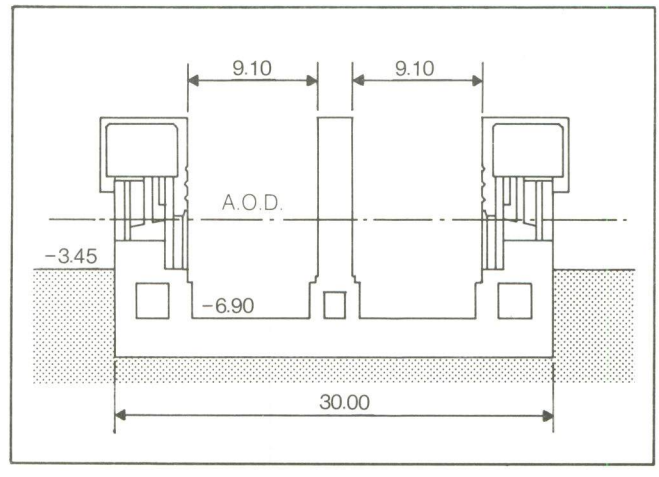
Gate-operating machinery and pumping station

Wall openings and perforated floor of the locks, which form part of the fresh/saltwater separation system.



Pleasure craft locks

These are twin locks with a dividing wall, the lock piers being equipped with two revolving gates with an automatic locking device which prevents the gates from opening if the water level in the lock is not equal to that outside it. These locks also have a fresh/saltwater separation system, but in this case the work of the reservoirs is done by a pump linked by culverts directly with the Eastern Scheldt and the lock chambers. The pump has a capacity of 4 m3 per second.



Cross-section of the pleasure craft locks

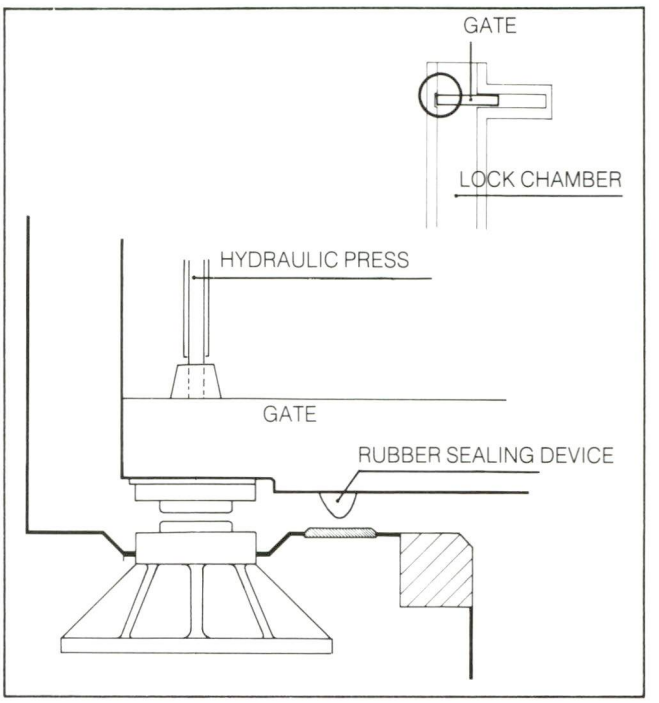
The pleasure craft lock site ready to be flooded.

Construction of the locks

Enormous quantities of concrete were required for the Krammer locks. The construction of the 280 metre push-tow locks with their concrete walls several metres thick, double flooring and network of huge culvert pipes called for a concrete works on the construction island itself, consisting of a conveyor system for sand and gravel, two cement silos, mooring wharfs, a hot water installation and storage tanks with metering devices for the various additives required. The concrete factory had a capacity of 230 m3 per hour, while the silos had a storage capacity of 1200 tonnes. There was also a special site for storing and processing the steel for reinforcing the concrete, where 6,000 tonnes could be stored and a weekly production of 400 tonnes could be achieved. The locks were constructed in 14-metre sections poured in 5 consecutive operations. An ingenious system of shuttering was devised for this purpose which allowed to rapid handling so that the shuttering would be in place ready for the following pouring operation.

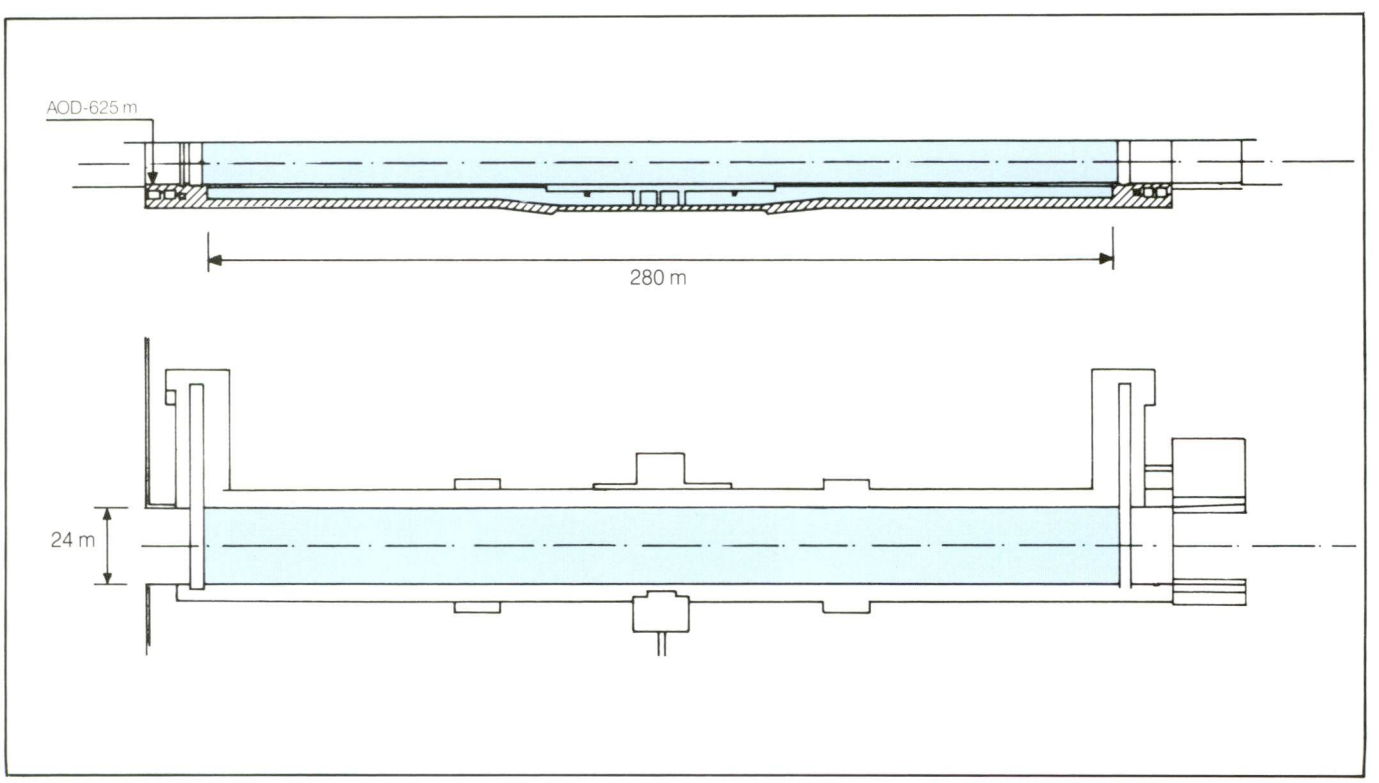
The power supply for the Krammer locks, 4000 kVA, is provided by the Zeeland Provincial Energy Authority whose service facility contains a high-tension distribution station and two diesel-powered emergency generators each capable of producing 725 kVA. The complex system of machinery for the variety of discharge and filling programmes required in a lock complex with a fresh/saltwater separation system is controlled by a computer which performs the necessary calculations and continually monitors operations.

Obviously, if the salt/fresh separation system is to function adequately the lock gates must seal well. The push-tow locks are equipped with hydraulic sliding gates which are constantly being forced against the wall of the lock chamber. The gates in the inlet, outlet and discharge sluices have a variable-speed drive system and rubber sealing devices. The 258 openings in the walls of the lock chamber which regulate the two-way flow of fresh water can also be opened and closed by means of sliding panels.



Closing mechanism of a sliding gate in the push-tow locks.

Cross-section and ground plan of a push-tow lock.





Pouring the concrete for a section of a culvert.

Pouring concrete for the walls of the push-tow locks in consecutive sections.



Approach harbours

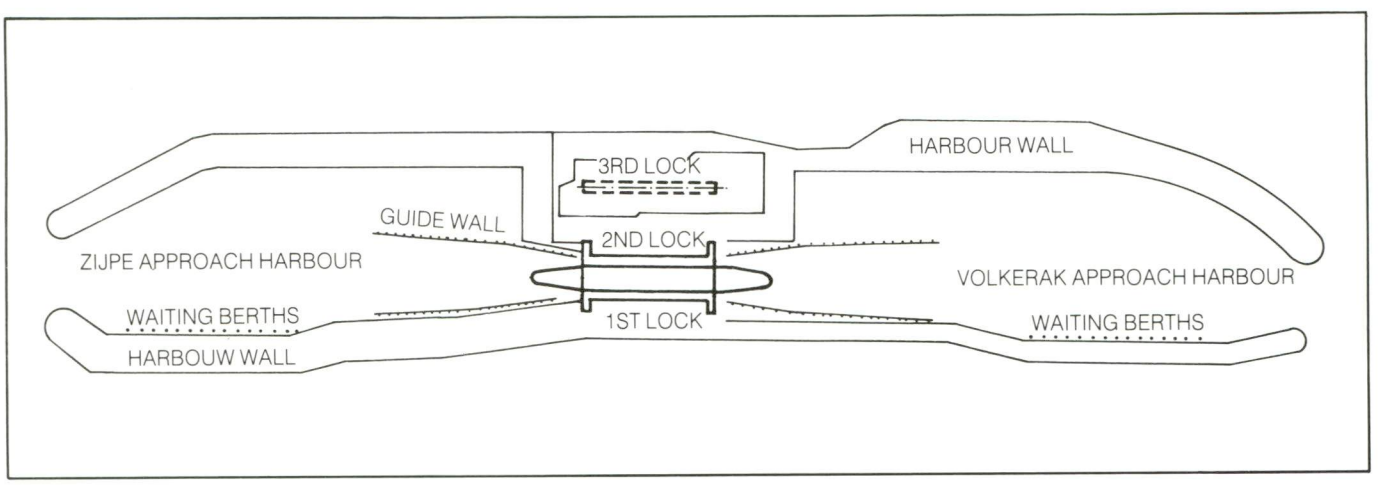
Since the Krammer locks, like the Volkerak locks to the north-east, are situated on a busy shipping route, extensive approach harbours with a length of approximately 1500 metres were built. They were designed for a configuration with three push-tow locks, in case the third lock should ever be required, and they extend to a depth of 7 metres below A.O.D.; the width of the channel at this depth at the entrance is 150 metres. The approach harbours are enclosed by dams which were also designed to:

- serve as a guide for shipping;
- prevent the formation of currents in the period before the completion of the Philips dam;
- reduce the intrusion of waves;
- provide road links with the shore.

The approach harbours are equipped with waiting berths and guide walls. Ships are guided into the lock via a queuing area and a funnel-shaped area formed by the guide walls on one side and a central guide jetty on the other. The waiting berths are for the use of shipping at the back of the queue which will have to wait for some time, perhaps even until the following day. The Zijpe approach harbour on the Eastern Scheldt is equipped with a floating guide wall to counteract tidal influence.



The Volkerak lock complex



Location of the guide walls and waiting berths in the approach harbours at the Krammer locks

The ring dike under construction



Bridges

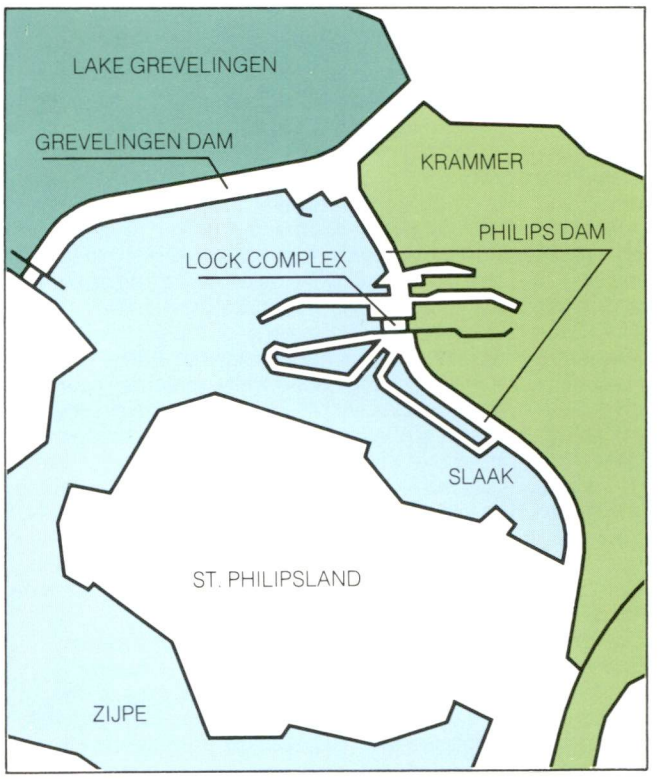
A 650 metre-long road bridge crosses the entire lock complex. A bascule bridge spans the northern pushed barge lock, so that at least one of the locks offers unlimited clearance for shipping. The bridge platform consists of pre-stressed concrete beams resting on 20 concrete piles and two abutments. Each span is approximately 30 metres in length. The components of the temporary bridge have been incorporated in the permanent bridgeworks. The highest point of the bridge is above the yacht locks (clearance: 18.5 metres); the underside of the bridge at the push-tow locks allows a clearance of about 14.5 metres.
The locks are provided with control rooms and a utilities block containing offices, the operating computer, transformers and the emergency generators. Once the locks had become operational the sections of the Philips dam which link the lock complex with the Grevelingen dam on one side and with St. Philipsland on the other could also be completed. The ring dike enclosing the lock complex first had to be dredged away, of course, in order to make the locks accessible to shipping.
It was decided that the section of the dam between the locks and St. Philipsland should be situated well to the east in order to keep as large as possible an area of the mudflats to the north of St. Philipsland under tidal influence. Wherever possible, the connecting road on the shore has been routed so that it avoids crossing farmland.
The Philips dam and the lock complex were completed in 1987.



The lock complex shortly before completion.







The lock complex in the Philips dam

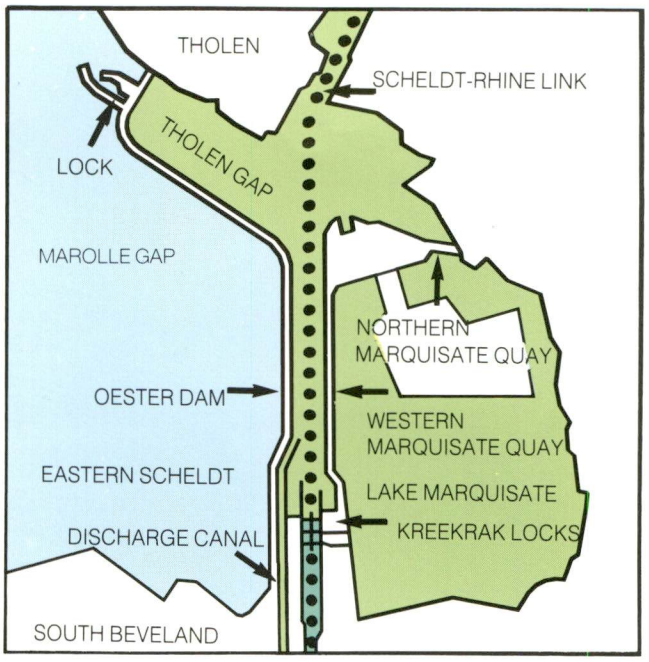
Placing the prefabricated pre-stressed T piles for the bridge over the Krammer locks

The utilities block at the Krammer locks.



The Oester dam

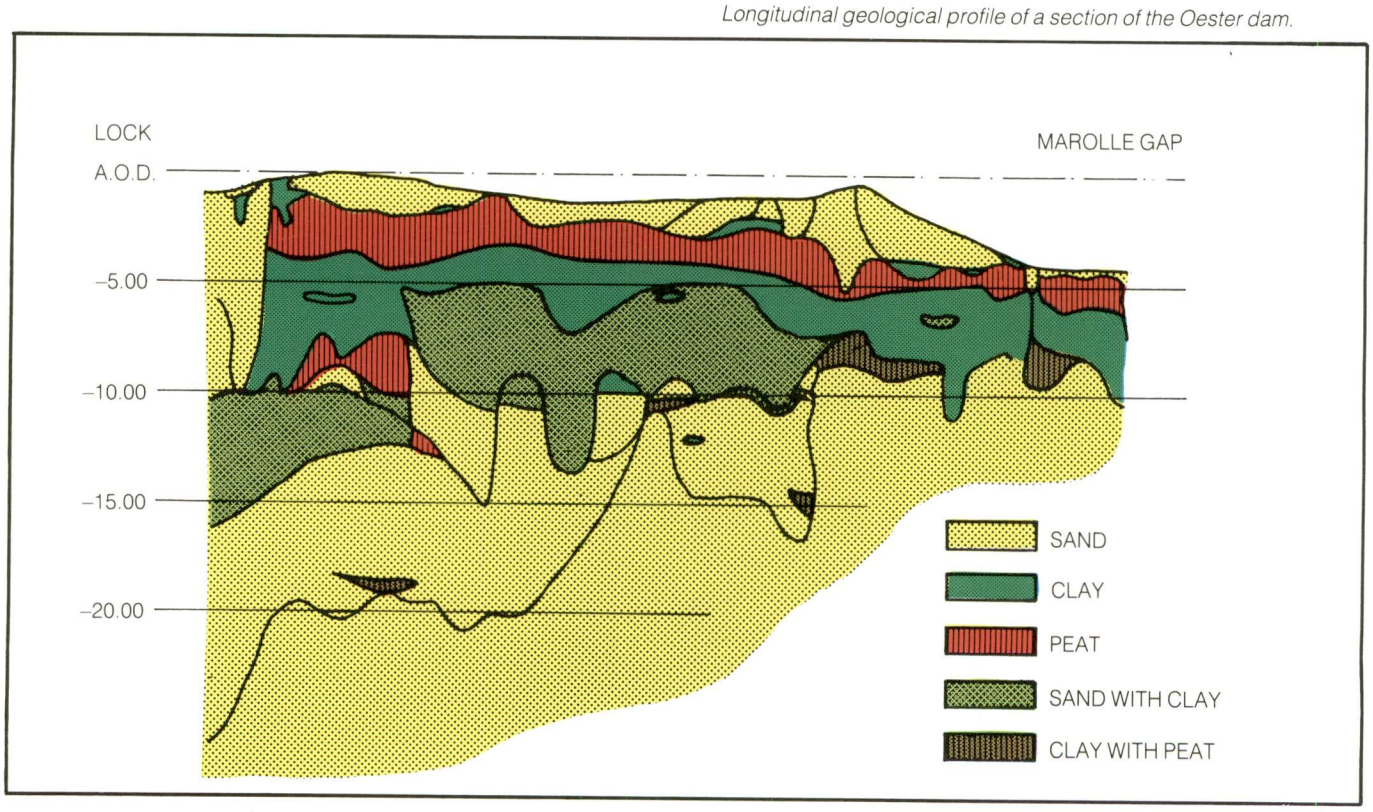
The second compartmentalisation dam is the Oester dam, situated in the eastern section of the Eastern Scheldt between Tholen and South Beveland. This dam closes off the Scheldt-Rhine link from the Eastern Scheldt. On the Tholen side of the dam there is a lock for the use of small vessels sailing between the Eastern Scheldt and the peripheral lake; this lock is 34 metres long and 6.5 metres wide and is spanned by an opening bridge. The sill depth on the Eastern Scheldt side is 4 metres below A.O.D. and on the peripheral lake side 2.5 metres. The lock is important for pleasure craft and fishing vessels.
The Oester dam crosses two navigation channels, the Tholen Gap and the Marolle Gap. The northern section of the dam was kept well to the west, running parallel to the coast of Tholen for some time before linking up with it. This was to prevent shipping in the Scheldt-Rhine link from being subjected to unnecessarily strong transverse currents during work on the closing of the Tholen Gap. The road along the dam links up with a road along the shore which follows a watershed in the Schakerloo polder, so no inroads had to be made in the natural landscape in the course of construction work. The southern section of the dam forms the western bank of the discharge canal which enters the Western Scheldt at Bath.
The longitudinal geological profile of the bed of the Eastern Scheldt where the dam is situated shows clearly the erratic nature of the composition of the estuary bed at the site. The section bordering the Scheldt-Rhine link was so poor that the weaker layers had to be reinforced with sand. In places where there was already an upper layer of sand several metres thick, this expensive process of reinforcement could be eliminated by building the dam in stages. This meant that large sections of the dam had to be filled in gradually with gently sloping layers until the subsoil had adjusted sufficiently to enable the dam to be built up to the required level. The top of the dam is 5.6 metres above A.O.D. A single carriageway road runs along the top, with a parallel road for agricultural and service vehicles.



The Scheldt-Rhine link between the Oester dam and the Marquisate Quay

Right: the construction island for the lock in the Oester dam. In the background, the Kreekrak locks.

Longitudinal geological profile of a section of the Oester dam.





The Marquisate Quay

In order to prevent excessive current velocities near the Tholen bank and the formation of strong transverse currents which would hinder shipping in the Scheldt-Rine link during the construction of the Oester dam, the area of water to the east of the Oester dam had to be reduced in size. To this end the inundated land in the Marquisate area near Bergen op Zoom was enclosed with a quay wall. This produced an area of approximately 2000 ha. where the marine environment could gradually adapt to the new situation. It has also made possible urban extension in Bergen op Zoom and the creation of additional recreational facilities in the area. Partly for the purpose of the former, a neck of land with an area of about 160 ha. was created in Lake Marquisate using sand produced by the excavation of the Bath discharge canal. This means that the Scheldt-Rhine link follows a course between the Oester dam and the Marquisate Quay.

The western section of the Marquisate Quay and the Kreekrak lock complex.

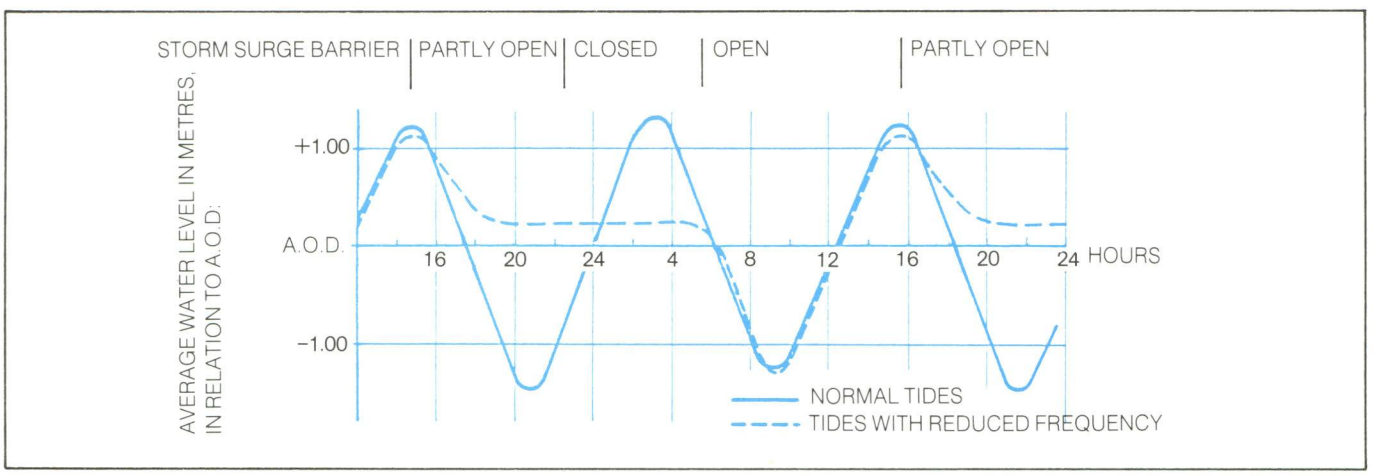


Closing the Channels

The compartmentalisation dams intersect four different channels. All four of them – the Marolle and Tholen Gaps in the Oester dam and the Slaak and Krammer channels in the Philips Dam – were then closed off in turn using dredged sand.
In the case of the secondary channels (the Marolle Gap and the Slaak) the gaps were gradually reduced in size as a sand dam was constructed in a southerly direction. More sand was lost as the channel velocities increased, but since the main channels were still open, the sand loss was restricted and it was possible to close the gaps.
In the case of the main channels, the drop over the gap was so great that a sand dam was not feasible. However, it was possible to use the storm surge barrier to influence tidal flow in the Eastern Scheldt in such a way that current velocities in the closure gap, and therefore also sand loss, were kept within limits. In closing the Krammer channel the principle of 'retarding' and 'reducing' tides was applied: the tidal cycle was retarded from twice a day to once a day. The tidal range was gradually reduced in the final stage of the project, and the storm surge barrier had to be closed completely for the last 1-2 days. A stone wall had been considered as a means of closing the Tholen Gap, but this method proved to be much more expensive, and it had few advantages over a sand dam.



Suction dredgers obtaining sand from sites near a closure gap



The average vertical tidal range during closure of the channels.

Pumping up sand for the sand wall





The construction island for the Philips dam with the Slaak (right) and the Krammer (left) closure gaps.

The Molenplaat sandbank with (top right) the construction island for the Tholen Gap lock and closure gap



Closing the Marquisate Quay

The Marquisate Quay was closed in the spring of 1983. The gap, with a breadth of 800 metres and an average depth of two metres below A.O.D., was closed vertically by construction of a containing wall in consecutive layers. This was done principally at low tide by lorries and tipper trucks. The winter closure gap and the final section of the first layer of stone were placed by special stone-dumping vessels. When the wall had reached the required height a sand wall was added behind it in such a way that a large proportion of the stone could then be removed and used elswhere for another part of the project.



Tipper trucks dumping stones at low water.

The quay wall and cranes at low tide

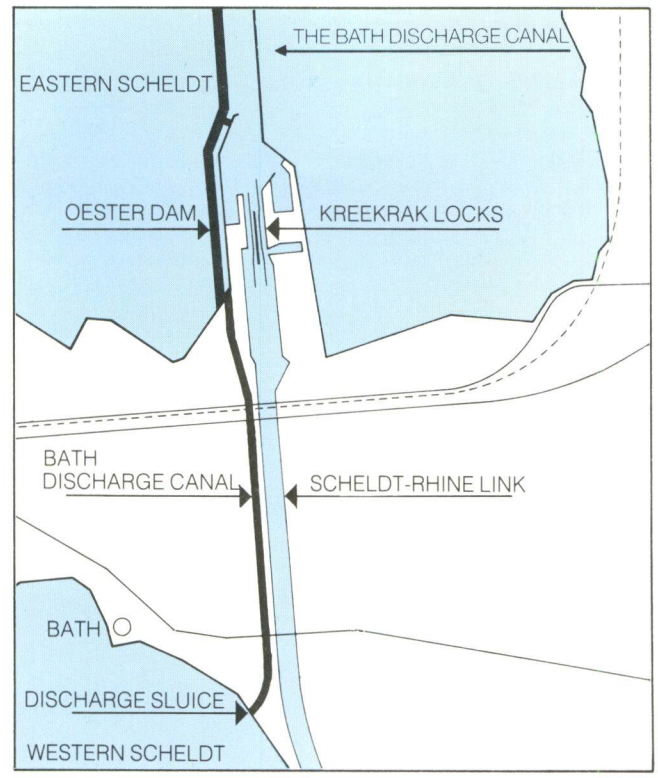


The Bath discharge canal

A great deal of the water in the surrounding countryside drains into the peripheral lake behind the compartmentalisation dams which stretches from the Volkerak dam in the north to the Kreekrak locks in the south. The lake is thus a reservoir for excess water in the area. In order to permit control of water levels and water quality it is desirable to have facilities for allowing water to enter the lake and for removing excess water.
Fresh river-water can enter the peripheral lake via the Volkerak inlet sluices, but for evironmental reasons fresh water cannot be discharged into the Eastern Scheldt. Nor can water be discharged into the southern section of the Scheldt-Rhine link because the water level in this canal is 1.8 metres higher than that in the lake. This would only be possible if pumps were used and owing to high energy costs this option was dismissed. This accounts for the decision to discharge excess water into the Western Scheldt via the Bath canal. The water in the Western Scheldt is also salt but environmental requirements are less stringent there than in the Eastern Scheldt, since the quality of the water is also influenced by the fresh water in the river Scheldt and the large-scale discharge of water from polders and waste waters. Water from the peripheral lake is carried to the Western Scheldt via an 8-kilometre discharge canal which runs across the neck of South Beveland. At low tide the water in the Western Scheldt is lower than in the lake so that pumps are not required. A discharge sluice was built at the southern end of the canal near Bath on the Western Scheldt so that the water can flow into the Western Scheldt. At high tide the sliding gates are lowered to prevent salt water flowing into the canal and to prevent flooding of the agricultural land in the vicinity. As an additional safety measure there is an emergency gate which closes automatically under the pressure of the water at high tide.
On its way south the canal crosses the following before entering the Western Scheldt via the discharge sluice:

- a pipeline viaduct
- National highway 258
- the Flushing-Roosendaal railway line
- National highway A58
- two series of pipelines
- the Bath road
- a drainage canal.

The intersections with the pipeline viaduct and the national highways can take the form of fixed bridges since no shipping passes through the canal. The other pipelines run in culverts under the canal and in order to drain the land east of the Scheldt-Rhine link continuously a siphon was constructed under the canal with two tunnels with a cross-section of 2.7 x 2.00 metres and a floor depth of 11 metres below A.O.D.
Part of the 8 million cubic metres of soil produced in digging the canal was used for the construction of the southern section of the Oester dam and for the neck of land which was created in Lake Marquisate.



Route followed by the Bath discharge canal



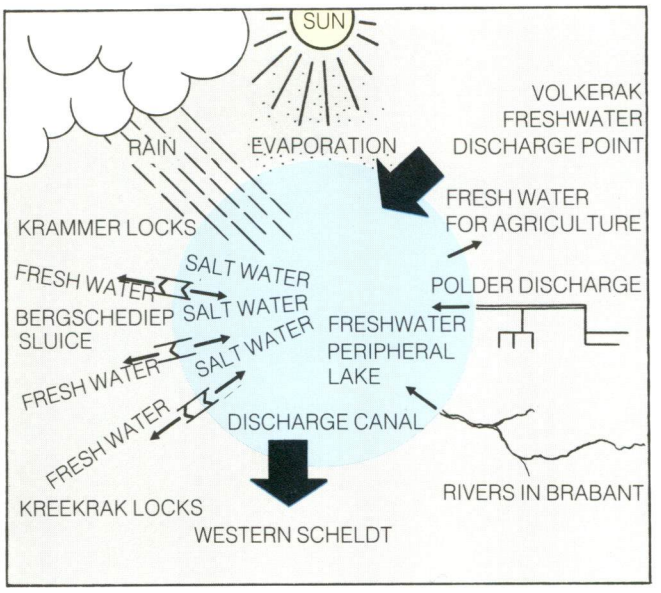
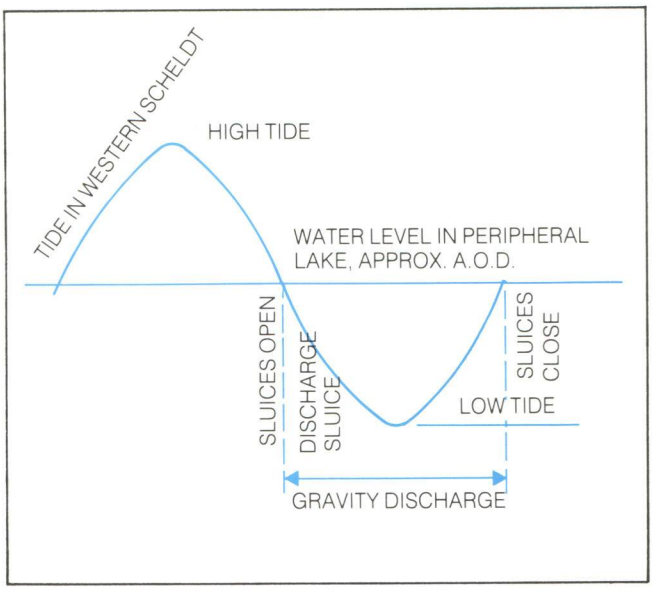
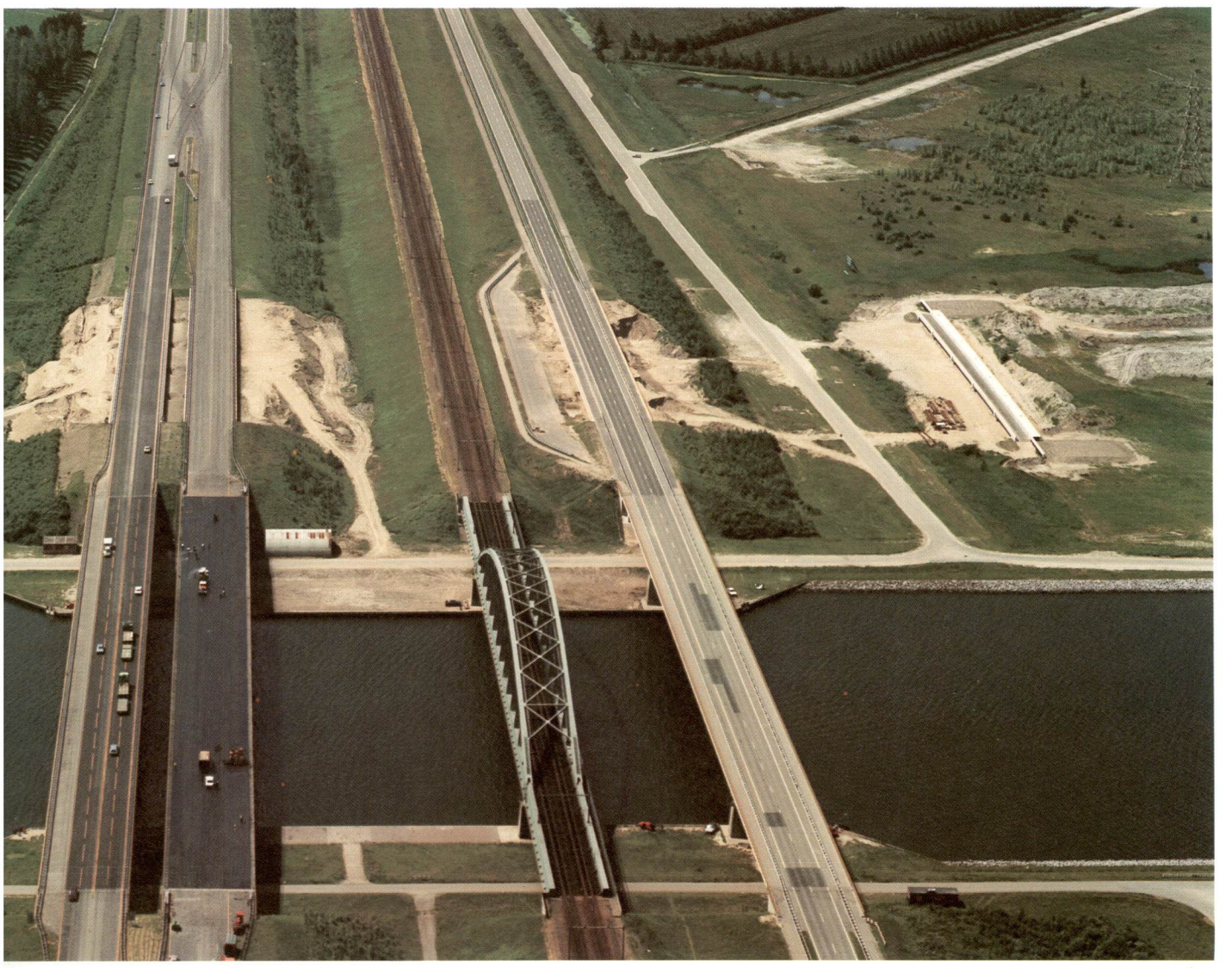


Diagram of the water balance in the area



The discharge phase in the Bath discharge canal

View of the bridges over the projected discharge canal. From left to right: National Highway A58 (dual carriageway), railway bridge, National Highway 258 and the pipeline viaduct.





The route of the discharge canal runs parallel to the Scheldt-Rhine link.

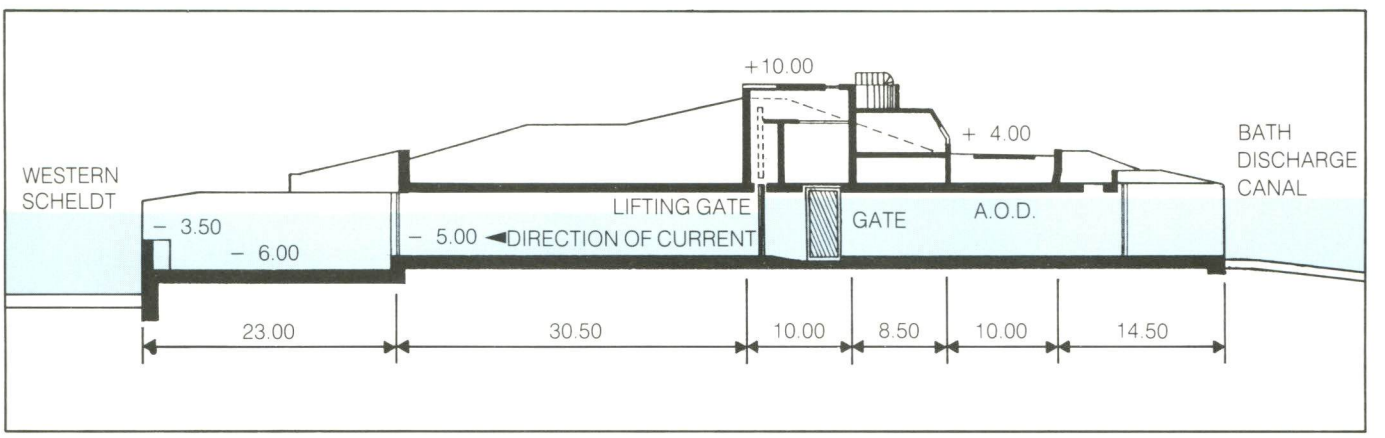
A drainage canal carrying water from West Brabant crosses the discharge canal by means of a siphon.



The Bath discharge sluice

The discharge sluice near Bath has an average capacity of over 24 hours of 100 cubic metres per second through a total of six tunnels. Consideration was also given to a siphon pump system but the present system of tunnels and a free-fall drop proved the most satisfactory solution. Discharge through the tunnels is regulated by a system of lifting gates. When the flow of water is slight, one or more of the tunnels are sufficient for discharge purposes.

The principle used for the sluice, which acts as a spillway, causes high current velocities and without preventive measures the floor would be washed away. For this reason a protective layer of concrete blocks and stone was employed. For hydraulic engineering and economic reasons a sill depth of 5 metres below A.O.D. was chosen; the top of the tunnels is at 0.25 metres above A.O.D. The high velocity of the water being discharged – 5 to 6 metres per second – necessitated the construction of a wide outlet to the sluice in order to reduce the velocity at the point of discharge. For this reason the concrete floor of the outlet area was built one metre lower than the floor of the tunnels, i.e. 6 metres below A.O.D. and the walls of the outlet section gradually widen over a distance of 20 metres from the mouths of the tunnels. At the outer end of the outlet section a 2.5 metre high serrated wall was constructed to distribute the current as it flows out onto the concrete-reinforced bed of the Western Scheldt. The sluice was built in a construction dock which had been pumped dry and rests on a foundation of 570 concrete piles.



Cross-section of the Bath discharge sluice

The outlet into the Western Scheldt showing the serrated distribution wall.

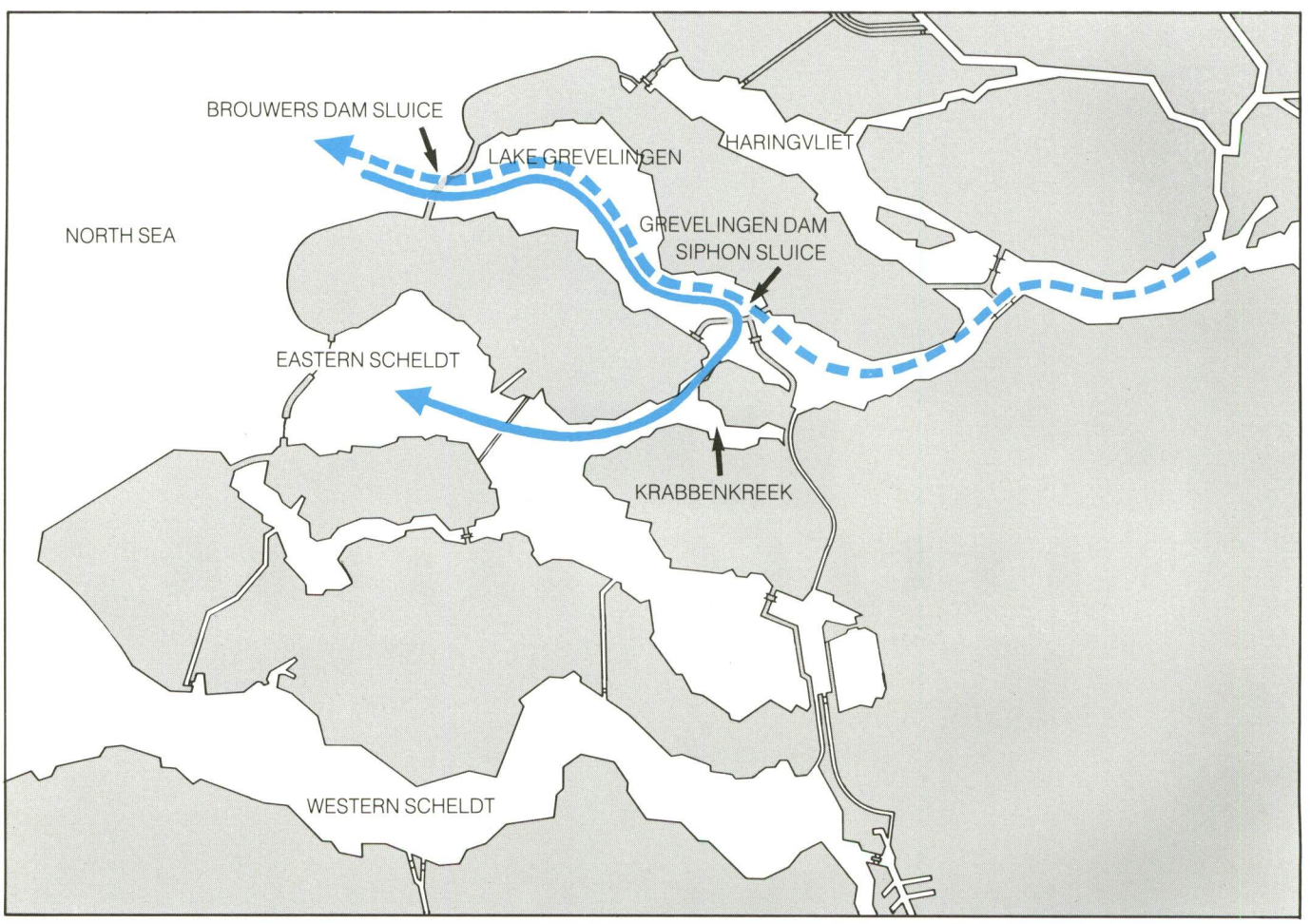


The Lake Grevelingen siphon sluice

One piece of construction work not directly connected with the compartmentalisation works is the sluice in the Grevelingen dam. This sluice, known as the Flakkee sluice, is designed to control the quality of the salt water in Lake Grevelingen and the Eastern Scheldt by siphoning off the water in Lake Grevelingen. In the seventies a discharge sluice was built in the Brouwers dam, which forms the western boundary of Lake Grevelingen, to enable salt water from the North Sea to be added to the stagnant salt water in the Lake. It can also be used to discharge water from the lake into the North Sea. This is necessary in order to maintain the salt content of the water in Lake Grevelingen which is 'contaminated' by, among other things, the discharge of fresh water from the polders. The new siphon sluice in the Grevelingen dam makes it possible to discharge water into the Krammer which flows directly into the Eastern Scheldt. In this way Lake Grevelingen can be 'flushed' with seawater which enters by way of the Brouwers dam and passes into the Eastern Scheldt by way of the siphon in the Grevelingen dam. In the final stages of the Delta project this arrangement ensured that the salt content of the water in the northern section of the Eastern Scheldt and the Krabbenkreek was maintained. This was necessary because, in the period before the compartmentalisation dams were completed, precipitation, fresh water from the Volkerak and water draining from the polders would have caused the salt content there to fall. In order to prevent damage to the marine environment during this period the Flakkee discharge sluice had to direct water of sufficient salinity to the Eastern Scheldt.

If ever it should be decided to make Lake Grevelingen a freshwater lake, the Flakkee sluice could be used to direct water in the opposite direction. In this case the sluice will have to be extended through the Philips dam to the planned freshwater peripheral lake behind it. From there fresh water can be directed to lake Grevelingen and discharged into the North Sea through the sluice in the Brouwers dam. The salt water would thus be forced out of Lake Grevelingen. The Flakkee and Brouwers dam sluices would thus discharge water in the opposite direction to that which would apply if Lake Grevelingen were to remain a saltwater lake. However, it was decided in 1986 that it should remain a saltwater lake, at least for the time being.

Ways of flushing Lake Grevelingen
Continuous line = movement of salt water
Dotted line = movement of fresh water





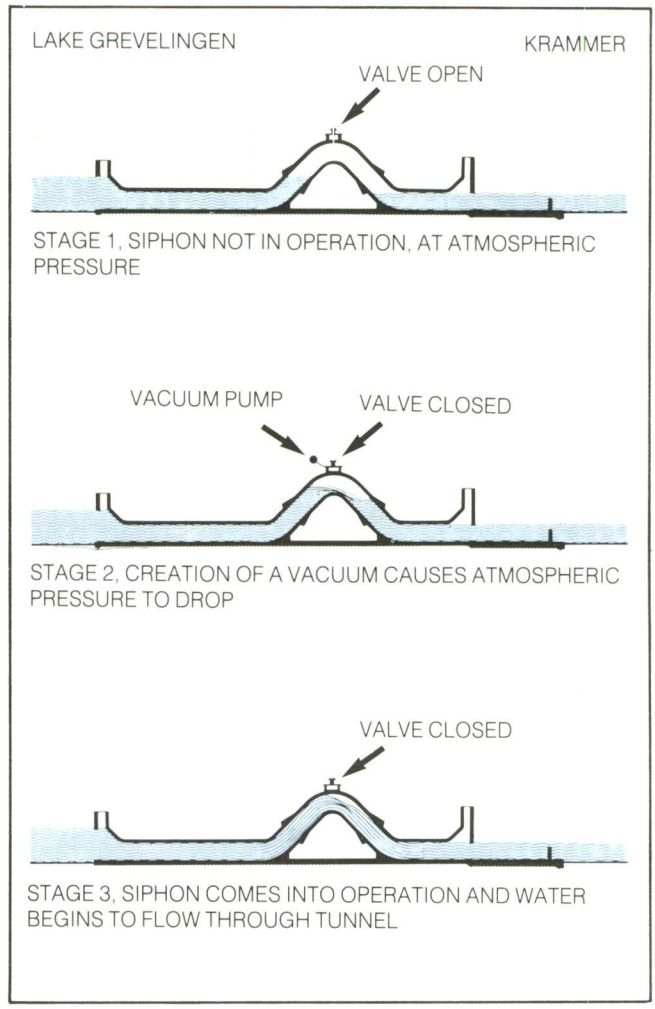
The siphon sluice in the Grevelingen dam

The Brouwers dam sluice



The construction of the siphon

The siphon consists of arched tunnels in the Grevelingen dam which form a link between Lake Grevelingen and the Eastern Scheldt. The upper section of the tunnels is an inverted U-bend, the underside of which is situated above mean highwater level. This means that the water cannot normally flow through the tunnels. In order to activate the siphon, air is extracted from the upper section by means of a vacuum pump. The water then rises to fill the ensuing vacuum and flows through the arch in a continuous stream from one side to the other.
The principle is the same as that used to empty a fish tank by means of a hose over the edge once the air has been siphoned out of the hose. The flow is stopped by allowing air to re-enter the arched section.
The siphon complex consists of two groups of three adjacent arched tunnels, each tunnel being 3.2 x 3.2 metres with a combined effective cross-section of 50 m2, the average capacity over a 24-hour period is equivalent to 80 m^3 per second.
Although the principle of the siphon is simple enough, additional hydraulic engineering research was required because of the dimensions of the project, particularly with regard to the operation of the siphon and the design of the outlet and reinforcement of the subsoil.
In periods when the water level in the Krammer is higher than 3 metres above A.O.D. the siphon begins to draw water automatically in the direction of Lake Grevelingen. This is counteracted by using a compressor to keep the air in the arched section under overpressure.



The principle of the Grevelingen dam siphon sluice

The arched section of the siphon under construction.



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