



WATER-RIGHT DOCKET

Cape Cod National Seashore

Docket No: 6

HIGHLAND GOLF COURSE TRURO WELL.

Supporting Hydro Data

00-00-0000: well drilling at highland golf course, highland light, truro information

WELL DRILLING AT HIGHLAND GOLF COURSE, HIGHLAND LIGHT, TRURO

John E. Cotton

Location of well. The well is near the southwestern corner of the Highland Golf Course (see figure 1). It is about 1600 feet south of Highland Light and about 1600 feet southwest from the coast.

Physical description of well. The well is 6 inches in diameter and is 90.1 feet deep with a 10.3-foot UOP Johnson stainless steel split screen (#20 from 79.8 to 86.8 and #30 from 87.1 to 90.1 feet). The well casing extends 1.1 feet above the land surface; the top of the first coupling is 3.8 feet below land surface. For further details see figure 2.

Geohydrologic description of well. The well is screened in unconsolidated sand. Table 1 is a log of the subsurface materials at the well site. The land surface at the well site is 71.4 feet above mean sea level. On May 19, 1970, the static water level was 66.09 feet below land surface or about 5.3 feet above mean sea level. Ocean tides have a small effect on the water level.

The well was pumped for 6 hours 45 minutes at 36 gallons per minute (gpm). At the end of 6 hours 35 minutes the drawdown (with an assumed correction for tidal influence) was 1.7 feet, giving a specific capacity of 21. About 95 percent recovery occurred within 30 seconds.

Estimating a late summer water table altitude of about 4 feet above mean sea level and following the arbitrary guidelines suggested for previous wells drilled during the past few years in the Park, the suggested maximum pumping rate would be about 40 gpm. Because higher yields from this well are desired for irrigation, a separate discussion of maximum yield follows the technical description of the well.

Chemical quality of water. Field determinations of temperature, specific conductance, chloride, and iron were made 9 times during the pump test. A complete chemical analysis (except iron and manganese determinations) was performed by the Survey's Albany laboratory of a sample taken 6 hours after the start of the pumping test. Iron, manganese, and free ammonia determinations were made on a sample taken 4 hours after pumping started (see table 2).

During pumping the temperature remained constant at 9.4°C and the conductivity was stable at 164-166 micromhos at 25°C. (The laboratory determination was 163 micromhos.) The chloride content during pumping remained steady; determinations were made by a relatively insensitive method and were all 45 milligrams per liter (mg/l). These values were 9 mg/l higher than the 36 mg/l value determined in the laboratory. The chloride values are within the normal range for fresh ground water on Cape Cod.

Field determinations of iron fluctuated between .06 and .10 mg/l during the first two hours of pumping and then decreased steadily to about .03 at the end of 6 hours. The laboratory analysis indicated an iron content of .00 mg/l. Manganese (.06 mg/l) was determined only in the laboratory analysis. Because manganese content of ground water from outer Cape Cod is commonly less than the iron content, these two constituents should be checked in the future.

Ammonia content was .13 and .06 mg/l in two samples. These values, while not high, are more than the ammonia content in 21 water samples (.00 to .04 mg/l) from test wells within the township of Truro. A possible source of the ammonia is fertilizer used on the golf course.

Test drilling. The only test well (4 feet east of the final well) was drilled to a depth of 110.5 feet. The log of this well is in table 1. The 6-inch casing was pulled back to 85.1 feet; no. 5 Cape May gravel was added during withdrawal forming a gravel column from 83 to 98 feet. Intermittent pumping for 6 hours provided water samples for initial estimates of chloride, iron, and specific conductance.

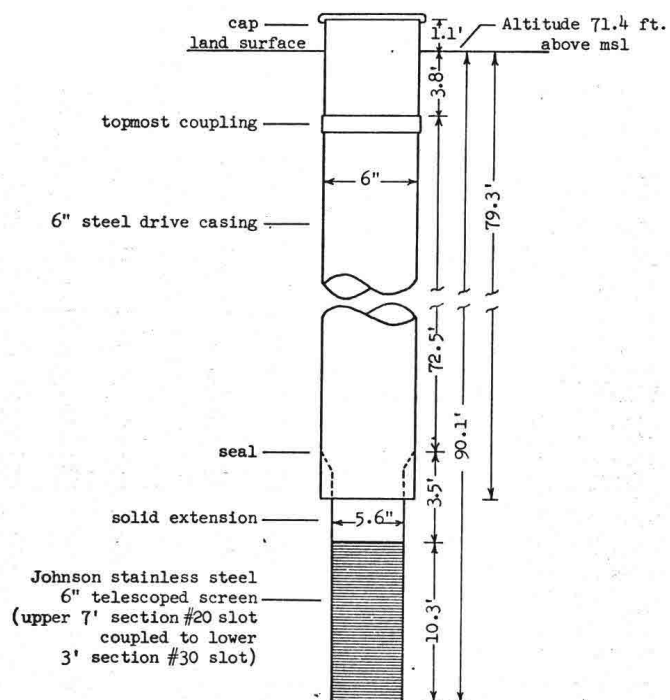


Figure 2.--Design of well at Highland Golf Course, Highland Light, Truro

Table 1.--Combined log of test well and final well at
Highland Golf Course, Highland Light, Truro

Sample interval (ft. below surface)	Material description
0-4	Sand; poor sample, eolian(?) silt and sand.
4-10	Sand and gravel; sand, very fine to very coarse, 10YR7/4 dry; predominantly coarse and very coarse; gravel, very fine to large cobble--4" or 5" in diameter--lag concentrate or old stream channel deposit. Predominantly quartz; minor feldspar shale chips (very coarse sand to very fine gravel).
10-15	Sand, fine to very coarse, predominantly medium and coarse; minor gravel, very fine to fine; color: 10YR5/4, moist; 10YR6/4, dry. Predominantly quartz; minor feldspar, perched water at 15 feet.
15-20	Sand, fine to coarse; some very fine, minor very coarse; color: 10YR5/4, moist; 10YR6/5, dry. Predominantly quartz; minor feldspar and shale.
20-25	Sand, fine to coarse, predominantly medium and coarse; minor very coarse; color: 10YR5/6, moist; 10YR6/6, dry. Predominantly quartz.
25-30	Sand, fine to coarse, predominantly medium; minor very coarse; color: 10YR5/2, moist; 10YR6/6, dry.
30-35	Sand, very fine to coarse, predominantly fine and medium; minor very coarse; color: 10YR5/5, moist; 10YR6/5, dry. Predominantly quartz. Little water in formation.
35-40	Sand, very fine to coarse, predominantly fine and medium; color: 10YR5/4, moist; 10YR6/5, dry. Predominantly quartz.
40-45	Sand, fine to very coarse, predominantly medium and coarse; minor very fine gravel; color: 10YR5/4, moist; 10YR6/5, dry. Predominantly quartz. Little water in formation.
45-50	Sand, fine to coarse, predominantly medium; color: 10YR5/4, moist; 10YR7/5, dry. Little water in formation. Predominantly quartz.
50-55	Sand, fine to coarse, predominantly medium and coarse; color: 10YR6/6, moist; 10YR7/6, dry. Little water in formation. Predominantly quartz. minor
55-60	Sand, very fine to medium, predominantly very fine and fine; silt; color: 10YR6/4, moist; 10YR8/4, dry. Predominantly quartz.
60-65	Sand, very fine to medium, predominantly very fine and fine; minor silt; color: 10YR6/4, moist; 10YR8/4, dry. Predominantly quartz.
65-70	Sand, very fine to coarse, predominantly fine and medium; color: 10YR6/4, moist; 10YR8/4, dry. Predominantly quartz.
70-75	Sand, very fine to coarse, predominantly fine and medium; color: 10YR6/4, moist; 10YR8/4, dry. Predominantly quartz.

Table 1.--Combined log of test well and final well at
Highland Golf Course, Highland Light, Truro--Continued

Sample interval (ft. below surface)	Material description
75-80	Sand, fine to very coarse; predominantly medium; color: 10YR6/4, moist; 10YR8/4, dry. Predominantly quartz.
80-85	Sand, fine to very coarse, predominantly medium and coarse; color: 10YR6/3, moist; 10YR8/3, dry. Predominantly quartz.
85-90	Sand, fine to very coarse, predominantly coarse; color: 10YR5/4, moist; 10YR7/4, dry. Predominantly quartz.
90-95	Sand, fine to very coarse, predominantly fine to coarse; color: 10YR6/5, moist; 10YR7/4, dry. Predominantly quartz.
95-97	Sand, very fine to coarse, predominantly fine; 10 percent silt; color: 10YR6/4, moist; 10YR8/4, dry. Predominantly quartz.
97-100	Sand, very fine to coarse, predominantly fine and medium; color: 10YR6/5, moist; 10YR8/5, dry. Predominantly quartz.
100-105	Sand, very fine to medium, predominantly fine; color: 10YR6/5, moist; 10YR8/5, dry. Predominantly quartz.
105-110.5	Sand, very fine to medium, predominantly fine; color: 10YR6/5, moist; 10YR8/5, dry. Predominantly quartz.

Table 2.--Complete chemical analysis, in milligrams per liter^{1/}, of water from final well at Highland Golf Course, Highland Light, Truro

Date of collection-----	5/19/70
Temperature (°C)-----	9.4
Silica (SiO ₂)-----	7.2
Iron (Fe) total-----	.00*
Manganese (Mn) dissolved-----	.06*
Calcium (Ca)-----	5.0
Magnesium (Mg)-----	2.6
Sodium (Na)-----	20
Potassium (K)-----	.8
Ammonia as (NH ₄)-----	.13, .06*
Bicarbonate (HCO ₃)-----	8
Carbonate (CO ₃)-----	0
Sulfate (SO ₄)-----	5.5
Chloride (Cl)-----	36
Fluoride (F)-----	.1
Nitrate (NO ₃)-----	.4
Dissolved solids	
Calculated-----	84
Residue on evaporation at 180°C-----	88
Hardness as CaCO ₃ -----	43
Noncarbonate-----	36
Specific conductance	
(micromhos at 25°C)-----	163
pH-----	6.5
Color-----	3

^{1/} Equivalent to parts per million.

* Determinations from sample taken after 4 hours of pumping; other determinations after 6 hours of pumping.

A crude estimate of the maximum safe yield of Truro 106
(New well at Highland Golf Course, Truro)

More water will be used from the well than from previous wells installed under the supervision of the Geological Survey because this well will supply water to irrigate the golf course. As pumping rates from wells in the marginal area of a fresh ground-water lens increase, so does the danger of inducing salt water intrusion. To delineate the highest sustained well yield without eventual contamination by salt water, several parameters must be known which are not known in this case:

- 1) Regional ground-water gradient and seasonal changes in this gradient
- 2) Depth to the bottom of the fresh-water lens and seasonal changes of depth
- 3) The physical extent of the aquifer, both laterally and vertically
- 4) Aquifer characteristics--coefficient of transmissivity (T), storage coefficient (S), and how permeability changes vertically
- 5) Tidal efficiency of the aquifer
- 6) Seasonal changes in ground-water recharge
- 7) Partial penetration correction for the well
- 8) Other nearby significant ground-water withdrawals

The known values are those obtained during installation and pumping of the test well and final well. These are:

- 1) Log of materials to a depth of 110.5 feet
- 2) Distance from the well to the coast
- 3) Altitude of the water table in May 1970
- 4) A 7-hour drawdown curve which was affected by tides
- 5) Estimated specific capacity based on the drawdown curve

The following determination of a maximum safe yield for this well is a crude estimate. Obtaining answers derived from using assumed values in simplified formulas based on assumptions that are not met is a dangerous game and is attempted only because some guideline should be followed for the pumping schedule of this well.

Vertical salt water encroachment. Salt water encroachment may occur vertically from below or laterally from the northeast. Vertical encroachment is considered first.

A static model of a fresh ground-water lens underlain by salt water requires a sharp boundary between fresh and salt waters, and 40 feet of fresh water below mean sea level (msl) for every foot of fresh water above msl. As the water table rises 1 foot, the fresh-salt water interface deepens 40 feet and vice versa. However, a dynamic model is necessary because waters of the two underground regimens mix and migrate seaward. Adjustments at the base of the fresh-water lens corresponding to seasonal variation in water table altitude may help form and maintain a zone of mixing. Meager information from the Outer Cape suggests the top of this mixed zone is at shallower depths than the 1 to 40 ratio of the static model. For example, at the middle of Great Island, Wellfleet, the ratio is 1 to 17. At Nauset Light, Eastham, 500 feet from the coast the ratio is unknown, but it is greater than 1 to 25.

About 1400 feet north of the new well (Truro 106) and 950 feet from the coast, "salt water" was reported 60 feet below msl in an unsuccessful well. It penetrated 175 feet of salt water before drilling stopped. Depth to the water table is not known, but it was probably between 2 and 4 feet above msl; this would indicate ratios between 1/30 and 1/15. Unfortunately, the depth to the bottom of the fresh water lens at The Highlands cannot be verified.

The distance from the well screen (Truro 106) to the bottom of the fresh water lens is given for several situations in table 3, assuming a late summer static water-table altitude of 4 feet above msl and a complete adjustment of the fresh water lens to that altitude and the cone of depression caused by sustained pumping.

Table 3.--Depth to brackish water from well screen
in late summer under assumed conditions

Pumping rate	Water level in well (in feet above msl)	Bottom of fresh water, in feet below well screen*					
		Ratio of $\frac{\text{fresh water above msl}}{\text{fresh water below msl}}$					
		1/15	1/20	1/25	1/30	1/35	1/40
Late summer static	4	40	60	80	100	120	140
Sustained 40 gpm	2**	10	20	30	40	50	60
Sustained 60 gpm	1**	0	0	5	10	15	20
Sustained 80 gpm	0**	0	0	0	0	0	0

* Well screen is assumed to be 20 feet below mean sea level. It is actually 18.7 feet below msl.

** Specific capacity is assumed to be 20; specific capacity was calculated as 21 after 6 hours 35 minutes of pumping.

Consideration of the information in table 3 suggests that 40 gpm may be the maximum safe sustained yield irrespective of the actual ratio of fresh water above msl to fresh water below msl. Lower permeabilities in the finer sand below the well screen (see table 1) serve as a small additional safety factor. It would be fortunate if a clay stratum was just below -40 feet which would provide a good seal and prevent vertical encroachment, but this is entirely unknown.

Lateral salt water encroachment. Salt water encroachment may occur laterally if the radius of the cone of depression expands 1600 feet to the coast. The drawdown at a specified distance from the well may be calculated for different discharges and lengths of time:

$$s = \frac{114.6Q}{T} W(u)$$

where s = drawdown, in feet, at any point in the vicinity of a well discharging at a constant rate

Q = pumping rate, in gpm

T = coefficient of transmissivity of aquifer in gallons per day per foot (gpd/ft)

W(u) = well function of u (for Theis nonequilibrium formula)

and

$$u = \frac{1.87 r^2 S}{T t}$$

where r = distance or radius, in feet, from center of pumped well to point where drawdown is measured

S = coefficient of storage

T = transmissivity, as above

t = time since pumping started, in days

To find out if the cone of depression would reach the coast by late summer:

let t = 90 days (June-August)

T = 200,000 (determined from a time-drawdown plot of water levels in pumping well)

S = .2 (estimated)

r = 1500 feet

Q = 40

The calculated drawdown at the coast after 90 days is .06 foot, indicating that cone of depression should just reach the coast. Drawdown values at different distances and two discharges are given in table 4.

Table 4.--Drawdowns, in feet, at the end of 90 days at various distances from the pumped well at two discharge rates

Discharge rate (gpm)	Distance from pumping well (in feet)			
	200	500	1000	1500
40	0.15	0.11	0.08	0.06
120	.45	.32	.23	.17

If the coefficient of transmissivity (T) of 200,000 (as determined from the first 40 minutes of the drawdown record of the pumped well) is too large, then the drawdown values in table 4 are too small. If T is assumed to be 100,000 instead of 200,000, then the drawdown in table 4 should be increased by about 50 percent.

Of course, one assumption of the original formula is that no recharge would occur during the 90-day period of pumpage; some recharge probably occurs in July and August on Cape Cod. This recharge would reduce the radius of the cone of depression. Some of the irrigation water might be recycled; this would also increase the effective recharge. Thus, considering just the possibility of lateral salt-water encroachment, the maximum safe sustained yield would be more than 40 gpm.

Maximum safe sustained yield. The maximum safe sustained yield cannot be determined with data available, but a conservative estimate apparently is limited by considerations of potential vertical salt-water intrusion to about 40 gpm.

Alternatives to pumping continuously at 40 gpm may be considered which would be more suitable for irrigation. Based on volumetric considerations of the dewatered zone in the cone of depression such alternatives are:

Pumping rate, in gpm-----	40	60	80	100	120
Maximum number of hours per day--	24	20	16	12	8

What the vertical adjustment of the fresh-water lens would be to shorter periods of higher pumping rates is not known, but complete hydrostatic adjustment probably would not occur. Nevertheless, the pumping level in the well probably should not be allowed to drop much below mean sea level. Assuming a static of +4 feet and using a specific capacity of 20, a pumping rate of 120 gpm would result in a 6-foot drawdown and a pumping level 2 feet below msl. However, the specific capacity of 20 was determined at a pumping rate of 36 gpm and would be less at 120 gpm. The actual drawdown at 120 gpm would be about 6.5 feet giving a pumping level of 2.5 feet below msl. A pumping rate of 100 gpm would result in a pumping level about 1.3 feet below msl. Therefore, the following alternatives are favored for determining the schedule of pumping:

Pumping rate, in gpm-----	40	60	80	100
Maximum number of hours per day--	24	19	14	8

If this schedule is followed, frequent tests for chlorides should be made. If the chloride content increases much above its present concentration, the pumping schedule should be reappraised.

Placement of pump. If the pumping rate should be set as high as 120 gpm at some time in the future, the top of the solid extension (see fig. 2) would be about 2.5 feet below the pumping level. If a submersible pump is used, as has been recent practice at the Seashore, it should be set inside the solid extension with the intake set at about 79 feet below the surface. Unfortunately, the contract specified a 6-inch well, instead of the 8-inch recommended by this office, because the opening through the seal is about $4\frac{1}{4}$ inches in diameter. Care is needed in selecting a 3-ft. long, 4-in. diameter pump that will deliver 100 gpm or more against a 75-foot head. If the same pump is to deliver water to the upper parts of the golf course, it will be working against a 125-foot head. Consideration should be given to installing a turbine pump.

Form 10-194
(Rev. 9/66)UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

EASTERN SERVICE CENTER

(Park)

Check One:

Monthly
Estimate☐Final
Estimate☒

UNIT PRICE CONTRACT

ESTIMATE NO. 1	FOR (Period) May 6, 1970 - to May 21, 1970	DATE June 3, 1970
CONTRACT NO. 14-16-7:993-490	COMPLETION DATE May 21, 1970	EXTENDED DATE --
CONTRACTOR The Able Drillers and Pump Company		ORIGINAL CONTRACT \$ 6,065.00
PROJECT Highland Lighthouse near Truro		CHANGE ORDERS* \$
LOCATION Cape Cod National Seashore		TOTAL CONTRACT \$ 4,136.75

ITEM NO.	CONTRACT QUANTITY	DESCRIPTION	QUANTITY TO DATE	UNIT PRICE	AMOUNT TO DATE
BID SCHEDULE A					
1	300 l.f.	Drill, case, remove casing and back-fill hole - minimum two (2) inch inner diameter hole.....	111 l.f.	4.75	\$527.25
2	12 hr.	Pump test for yield.....	6 Hr.	10.00	60.00
3	L.S.	Grouting a portion of a test hole, if deemed necessary by the Contracting Officer, which has been abandoned by direction of the Government through no fault of the Contractor.....	1 L.S.	00	00
4	12	Split spoon samples.....	0	00	00
Total Bid Schedule A					\$587.25
BID SCHEDULE B					
1	140 l.f.	Drill hole to receive six-inch (6") inside-diameter casing and two-inch (2") minimum grout ring.....	91 l.f.	15.00	\$1,365.00
2	140 l.f.	Furnishing and installing six-inch (6") casing and two-inch (2") minimum grout ring.....	81 l.f.	4.50	364.50

Form 13-194
(Rev. 9/60)UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

Check One:

Monthly
Estimate ☐Final
Estimate ☐

(Perk)

UNIT PRICE CONTRACT

ESTIMATE NO.	FOR (Period)		DATE		
CONTRACT NO.	COMPLETION DATE		EXTENDED DATE		
CONTRACTOR			ORIGINAL CONTRACT \$		
PROJECT			CHANGE ORDERS* \$		
LOCATION			TOTAL CONTRACT \$		

ITEM NO.	CONTRACT QUANTITY	DESCRIPTION	QUANTITY TO DATE	UNIT PRICE	AMOUNT TO DATE
<u>BID SCHEDULE B (Continued)</u>					
3	1 l.s.	Furnishing and installing six-inch (6") diameter, 10 feet in length, stainless steel well screen.....	1 l.s.	\$500	\$500.00
4	24 Hr.	Developing well, by pumping and surging.....	26 hrs.	40	1,040.00
5	8 Hr.	Pump testing for yield of well.....	7 hrs.	40	280.00
6	8 Hr.	Standby time for crew and equipment.	0	40	00
7	0 hr.	Abandonment of hole at the Government's request.....	0	200	00
Total Bid Schedule B					\$3,549.50
TOTAL UNIT PRICE CONTRACT					\$4,136.75

RECOMMENDED (Project Supervisor)		SUMMARY	
/s/ Garland Moore		TOTAL TO DATE..... \$ 4,136.75	
Garland Moore, Hydraulic Engineer, ESC-LW		LESS RETAINED AMOUNT..... --	
APPROVED (Contracting Officer)		NET..... --	
DATE		LESS PREVIOUS PAYMENTS..... --	
Ray G. Martinez, Chief, Division of Property Management & General Services		LESS LIQUIDATED DAMAGES..... --	
June 3, 1970		DUE THIS ESTIMATE..... 4,136.75	
% COMPLETED TO DATE:			

*Show Breakdown on Reverse (See Reverse for Distribution)

Maps and Miscellaneous Information

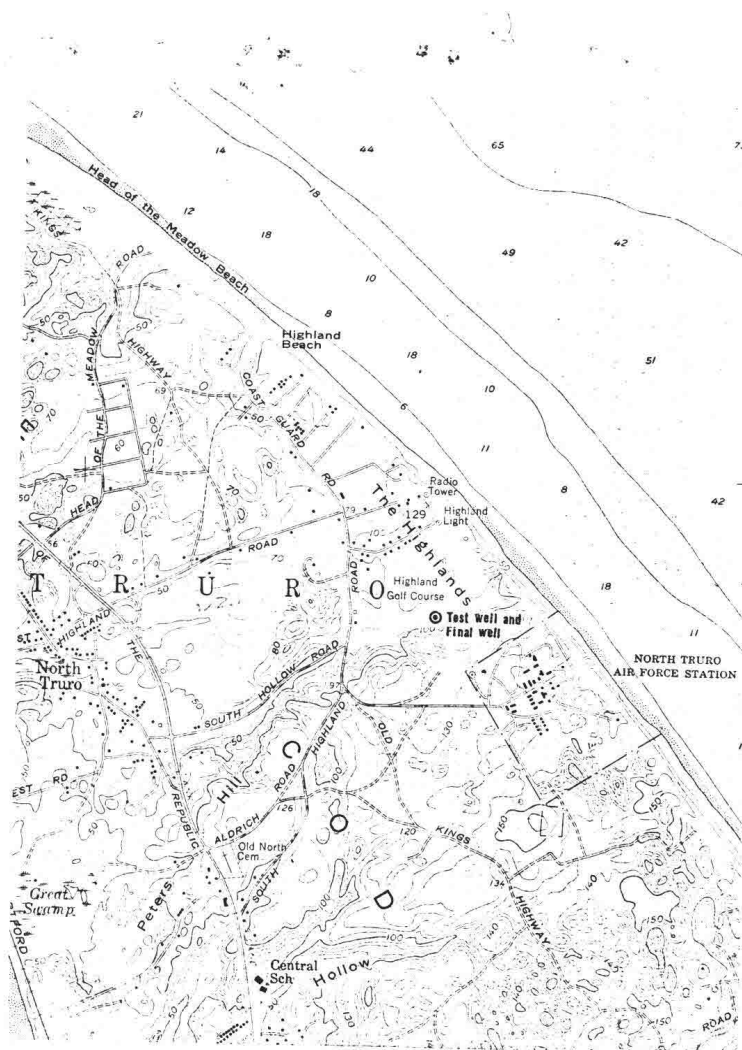


Figure 1---Location of test well and final well at Highland Golf Course, Highland Light, Truro

Docket Information

Number of Documents in Docket 15

Documents Dated from 5/19/1970 to 6/3/1970

Docket Compiled: 2/1/2011