Tidal Currents
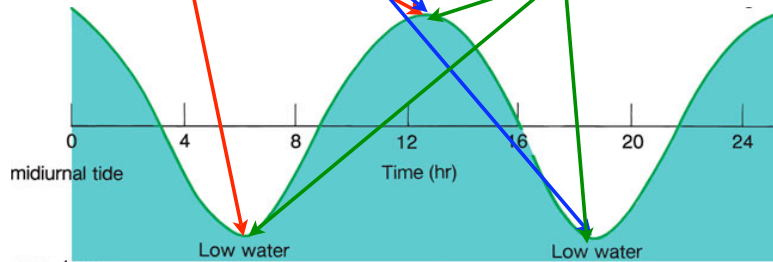
- As tide rises & falls, water moves laterally
  - Rising tide = flood current
  - Falling tide = ebb current
  - Tide turns, current = zero at slack water

midiurnal tide   0   4   8   12   16   20   24
Time (hr)
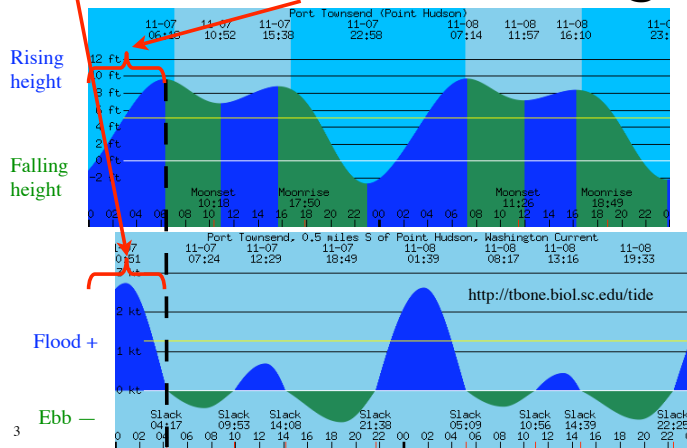Low water   Low water

1

Tidal Currents

- As tide rises & falls, water moves laterally
  - Water is very shallow compared to wavelength
    - Tidal wavelength 1/2 of Earth's circumference
    - "Orbits" compressed into long ellipses
  - Horizontal motion much greater than vertical

$D < \frac{L}{20}$

$d = \frac{L}{20}$

2
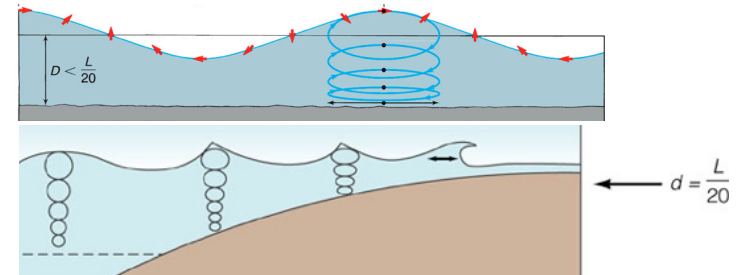
Tidal Currents

- Flood current as tide rises until slack @ HW

Rising height

Falling height

Flood +

Ebb —

http://tbone.biol.sc.edu/tide

3

Tidal Currents

- Ebb current as tide falls until slack @ LW

Rising height

Falling height

Flood +

Ebb —

http://tbone.biol.sc.edu/tide

4
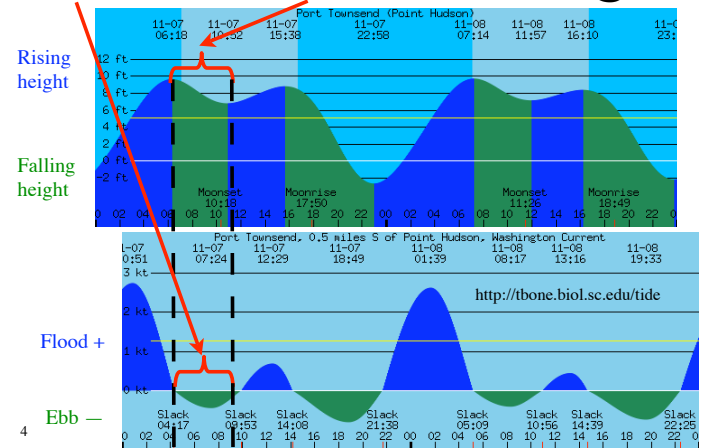
Tidal Currents

- Maximum speed halfway between HW & LW
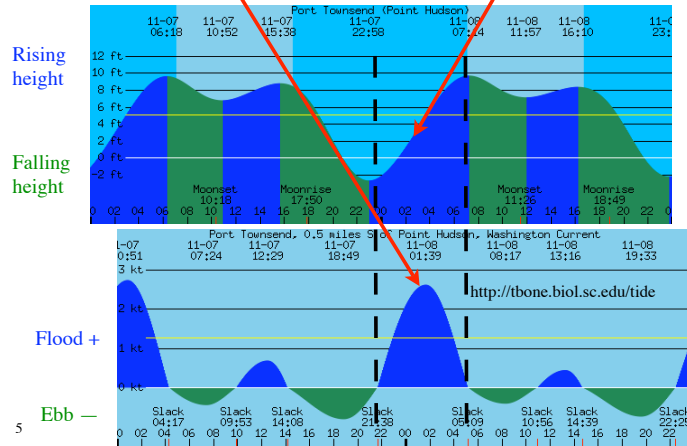
Tidal Currents
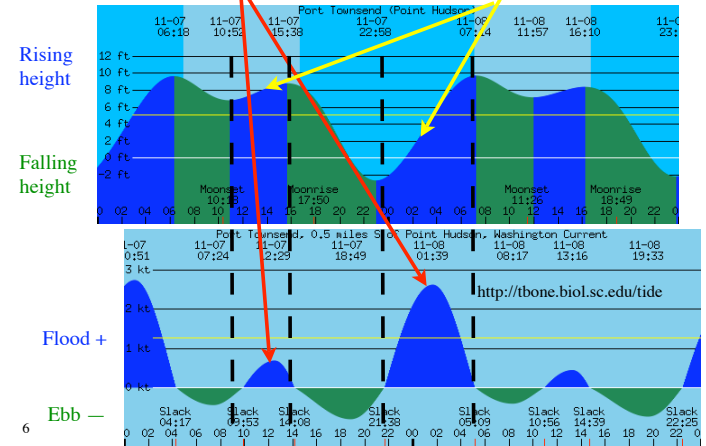
- Speed proportional to volume of tidal exchange

Tidal Currents

- Currents in inland passages
  - Large volume of water squeezing into a narrow shallow channel
    - Admiralty Inlet
    - Tacoma Narrows
  - Thumb over the garden hose
    - Volume of exchange reduced
    - Speed of exchange increased
  - Lag between the times of HW & LW and those of slack
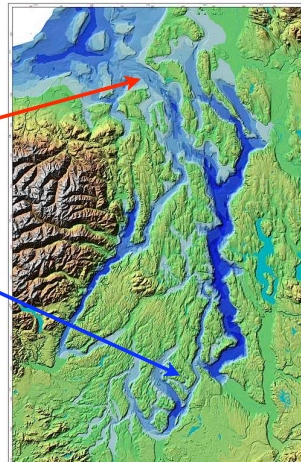
Tidal Currents

- Currents in inland passages
  - Sechelt rapids, BC ("Skookumchuck", Indian for "strong salt water") 14 knots
  - San Juan Islands 4–5 kt
  - Deception Pass 8 kt
  - Admiralty Inlet 4 kt
  - Tacoma Narrows 6 kt
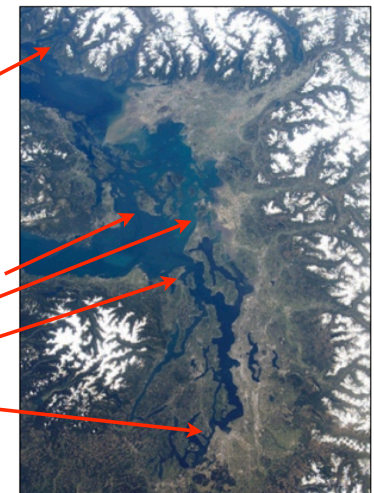
Skookumchuck

- Tidal rapids in both directions of tidal flow
  - Visible drop in water level
- Standing waves
  - www.surfingvancouverisland.com/surf/ st414skookumchuck.htm

www.rversonline.org/Skookumchuck.jpg

www.hightidetours.com/skookum.htm

9

Skookumchuck

- Tidal rapids in both directions of tidal flow
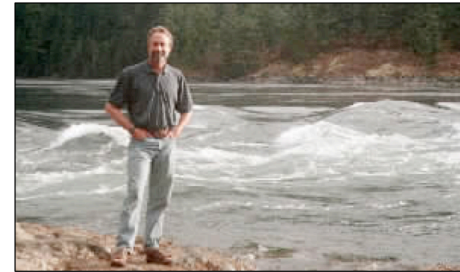 - Visible drop in water level
- Standing waves

10

Tidal Height/Current Predictions

- Derived from decades of observations of tide levels & currents by federal researchers
- Fit to statistical relationships by computer
  - 36 components of model include multiple aspects of lunar and solar gravity
    - Variations in orbital parameters
  - Different components are weaker & stronger at different locations
    - Quantifies effects of basin shape, etc.
  - Statistical correlations only, not a model using formulas for physical laws

11

Tidal Height/Current Tables

- Tidal prediction models
  - Govt. sells data to private publishers who print tables
    - Tabulated in newspapers & phone books
    - Maps also available with diagrams of tidal currents at different locations
  - Can be approximated by a simple model with 6 components of sun & moon
    - Models available for PC & Palm Pilot
  - Many web sites with tide tables

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Tidal Height/Current Tables

- Tidal prediction models
  - Model implicitly includes effects of location, bathymetry, basin shape, etc.
  - Reliable at predicting effects of astronomical factors and local bathymetry
    - Small errors from approximations in model
  - Other factors they can't predict cause errors
    - Winds & pressure change sea level by tens of cm
    - Wind & river flow & floods affect currents
    - Distance between location of computer prediction & your location

13

Tidal Measurements

- Tidal measurements now automated
  - Data continuously transmitted to NOAA servers via satellite
  - Posted to web for users

14   www.nos.noaa.gov/education/kits/tides/tides11_newmeasure.html
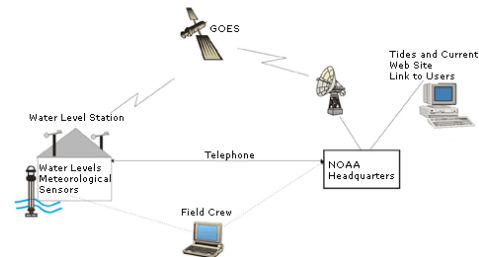
Tidal Prediction Accuracy

- Tidal prediction & measurements for Seattle
  - Nov. 5-7 2006 http://tidesonline.nos.noaa.gov/geographic.html
  - Effect of strong winds from S raising water level
    - Maybe low barometric pressure too

15
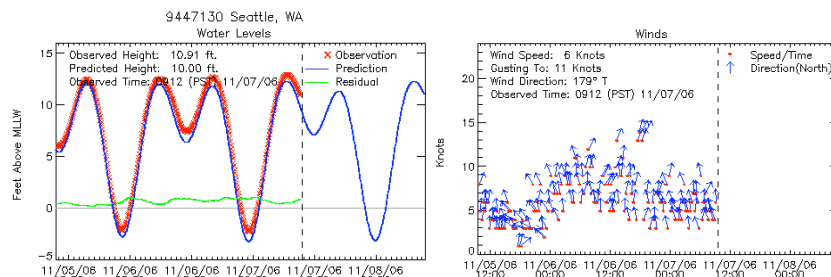
Tidal Height Predictions

- Predictions are calculated for a handful of "reference stations" (e.g., Port Townsend, Seattle)
  - "Differences" in time & magnitude at nearby locations are tabulated
  - Apply differences to reference values to obtain predictions at nearby locations
    - "Differences" ≠ "corrections"
    - Predictions are not in error

16
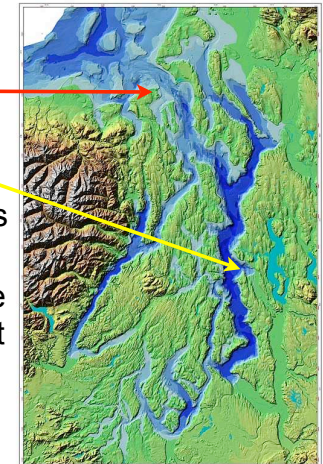
Tidal Prediction Scenario

- SCUBA diving fatality July 1995
  - In San Juan Channel, near Friday Harbor, San Juan Island

Woman, 21, disappears while scuba diving in the San Juans

PI STAFF 7.14.95

A 21-year-old woman disappeared yesterday while scuba diving with two companions in cold, fast-moving water near San Juan Island.

Coast Guard and San Juan County crews searched the area for 5½ hours without success. The search will resume today.

The unidentified woman was diving with two partners when they swam into strong currents off Turn Island east of San Juan Island.

The currents pushed them down to a depth of about 150 feet, Coast Guard Lt. Cameron Webster said

last night.

The other two divers were able to pull themselves out of the current and swim to the surface. But the woman, a less experienced diver, did not surface.

Dogs from the Issaquah Search and Rescue team were employed to search for a scent of the woman in the water, the San Juan County sheriff's office said.

The woman's parents also were on the scene.

The sheriff's office, the Friday Harbor Fire Department, San Juan County Aid and the Coast Guard searched for the woman.

Sheriff's divers searched for her until nightfall, aided by a Coast Guard helicopter and patrol boat and by civilian divers. More boats will join the search today.

The missing woman had a two-hour supply of air, but searchers said she could have been swept away by heavy afternoon tides and may have survived. They planned to resume a full search today during slack tide.

"Any time you have strong currents, diving is always a risky business," Webster said.

The popular diving area is very rocky, with very fast, deep tidal currents, he said.

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Tidal Prediction Scenario

- SCUBA diving fatality July 1995
  - Did the divers confuse the tidal height and current predictions?
    - Could have mistakenly dived at time of strong current, rather than at slack

Coast Guard suspends search for scuba diver

7.15.95

By ERIC HOUSTON
PI REPORTER

The Coast Guard yesterday suspended its two-day search for a 21-year-old woman who disappeared while scuba diving off the San Juan Islands.

The search ended without a trace of Hannah Core of Anchorage, who became caught in cold, swift currents with two other people off Turn Island Thursday.

Her companions were able to swim to the surface where they radioed for help, but Core did not reappear.

Rough waters have made conditions difficult for rescuers.

Core was on a dive charter with

the Friday Harbor-based Emerald Seas Diving and Marine Center. She was accompanied by a friend and a diving guide.

The owner of Emerald Seas, Tom Hemphill, last week was quoted in a local weekly newspaper as saying that strong tides and currents this week would make diving unsafe. Hemphill was with the search teams and could not be reached for comment yesterday.

A Coast Guard spokesman yesterday could not say whether conditions in the water were too dangerous when Core was reported missing.

The currents dragged the divers to a depth of about 150 feet, Coast Guard Lt. Cameron Webster said Thursday.

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Tidal Prediction Scenario

- SCUBA diving fatality July 1995
  - Friday Harbor (San Juan Island)
    - Nearest tidal height prediction
  - San Juan Channel
    - TIdal current reference station
  - Port Townsend
    - Nearest tidal height reference station

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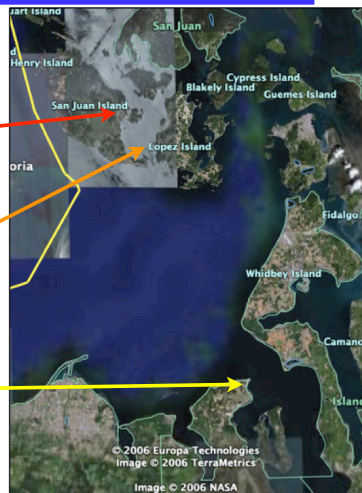
Tidal Height Prediction Example

- Port Townsend, Dec. 2005
  - Predicted times of high & low water in column 1
    - Military (24-hour) time
  - Local Standard Time
    - Convert to Daylight Time when needed
  - Predicted heights in column 2
    - Read high & low from values

Port Townsend, Washington, 2005
Times and Heights of High and Low Waters

		December					
	Time	Height			Time	Height	
	h m	ft	cm		h m	ft	cm
1 Th ●	0528	8.9 *	271	16 F	0617	9.8	299
	0924	7.4 *	226		1057	7.8	238
	1356	8.7 *	265		1417	8.2	250
	2140	-2.6 *	-79		2216	-1.9	-58
2 F	0612	9.4	287	17 Sa	0654	9.7	296
	1011	7.8	238		1154	7.6	232
	1422	8.8	268		1449	7.9	241
	2220	-3.0	-91		2254	-1.6	-49
3 Sa	0656	9.6	293	18 Su	0730	9.5	290
	1103	8.0	244		1254	7.3	223
	1455	8.7	265		1529	7.5	229
	2305	-3.0	-91		2333	-1.2	-37

*Highs
*Lows

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Slide 21

Tidal Height Prediction Example

- **Port Townsend, Dec. 2005**
  - Mixed semidiurnal tide
  - Predicted heights in column 2
    - Read high & low from values
    - Higher high water (HHW)
    - Higher low water (HLW)
    - Lower high water (LHW)
    - Lower low water (LLW)

Port Townsend, Washington, 2005
Times and Heights of High and Low Waters

December				
	Time	Height		Ti
	h m	ft	cm	h
1 Th	0528	8.9	271	16 06
	0924	7.4	226	F 10
	1356	8.7	265	14
●	2140	−2.6	−79	22

*Highs
*Lows

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Slide 22

Tidal Height Prediction Example

- **Port Townsend, Dec. 2005**
  - Order of tidal stages changes through the month
    - Read high & low from values
    - Lower low water (LLW)
    - Higher high water (HHW)
    - Higher low water (HLW)
    - Lower high water (LHW)

Port Townsend, Washington, 2005
Times and Heights of High and Low Waters

December				
	Time	Height		Ti
	h m	ft	cm	h
1 Th	0528	8.9	271	16 06
	0924	7.4	226	10
	1356	8.7	265	14
●	2140	−2.6	−79	22
9 F	0335	2.1	64	
	1111	9.5	290	
	1804	3.0	91	
	2356	5.8	177	

*Highs
*Lows

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Slide 23

Tidal Height Prediction Example

- **Port Townsend, Dec. 2005**
  - When are spring & neap tides?
    - New moon & quarter moons

1 Th	0528	8.9	271	16 F	0617	9.9	299	6 Tu	0043	−1.8	−55	21 W	0053	0.2	6
	0924	7.4	226		1057	7.8	238		0914	9.7	296		0910	9.0	274
	1356	8.7	265		1417	8.2	250		1509	7.0	213		1604	5.6	171
●	2140	−2.6	−79		2216	−1.9	−58		1754	7.1	216		1833	5.8	177
2 F	0612	9.4	287	17 Sa	0654	9.7	296	7 W	0137	−0.8	−24	22 Th	0134	1.2	37
	1011	7.8	238		1154	7.6	232		0956	9.6	293		0938	8.9	271
	1422	8.8	268		1449	7.9	241		1627	5.8	177		1648	4.7	143
	2220	−3.0	−91		2254	−1.6	−49		1943	6.3	192		2007	5.1	155
3 Sa	0656	9.6	293	18 Su	0730	9.5	290	8 Th	0234	0.6	18	23 F	0215	2.4	73
	1103	8.0	244		1254	7.3	223		1036	9.6	293		1005	8.9	271
	1455	8.7	265		1529	7.5	229		1720	4.5	137		1723	3.7	113
	2305	−3.0	−91		2333	−1.2	−37	☽	2147	5.7	174	○	2207	4.8	146
4 Su	0742	9.7	296	19 M	0805	9.4	287	9 F	0335	2.1	64	24 Sa	0258	3.6	110
	1204	8.0	244		1401	6.9	210		1111	9.5	290		1029	8.8	268
	1536	8.4	256		1618	7.0	213		1804	3.0	91		1754	2.6	79
	2352	−2.6	−79						2356	5.8	177				
5 M	0828	9.7	296	20 Tu	0013	−0.6	−18	10 Sa	0438	3.6	110	25 Su	0042	5.3	162
	1325	7.7	235		1144	9.2	280		1144	9.5	290		0349	4.9	149
	1631	7.9	241		1508	6.3	192		1844	1.5	46		1052	8.8	268
					1718	6.4	195						1823	1.5	46

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Slide 24

Tides at Difference Stations

- **Friday Harbor, San Juan Island**
  - Differences between times of H & LW
    - Compared to Port Townsend reference
    - HW +33 min. (later), LW +51 min. (later)
  - Differences between heights of H & LW
    - Compared to Port Townsend reference
    - HW x0.91 (smaller), LW x0.92 (smaller)

Dece		
Time	Height	
h m	ft	cm
0528	8.9 ★	271
1 Th	0924	7.4 ★ 226
	1356	8.7 ★ 265
●	2140	−2.6 ★ −79

No.	PLACE	POSITION		DIFFERENCES				RANGES		Mean Tide Level
		Latitude	Longitude	Time		Height		Mean	Diurnal	
				High Water	Low Water	High Water	Low Water			
		North	West	h m	h m	ft	ft	ft	ft	ft
	Rosario Strait, etc.			on Port Townsend, p. 28						
	San Juan Channel									
1203	Richardson, Lopez Island	48° 26.8'	122° 54.0'	−0 27	−0 12	*0.85	*0.84	4.55	7.17	4.36
1205	Shaw Island, Ferry Terminal, Harney Channel	48° 35.1'	122° 55.7'	+0 31	+0 56	*0.90	*0.99	4.40	7.63	4.73
1207	Friday Harbor, San Juan Island	48° 32.8'	123° 00.6'	+0 33	+0 51	*0.91	*0.92	4.82	7.76	4.70

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Tides at Difference Stations

- Predicted reference time + difference = predicted local time
  - HHW 0528 + 0:33 minutes = 0601
- Predicted reference height x difference = predicted local height
  - HHW 8.9 ft. x 0.91 = 8.1 ft.

		Dece
Time	Height	
h m	ft	cm
1 Th 0528	8.9	271
0924	7.4	226
1356	8.7	265
● 2140	–2.6	–79

No.	PLACE	POSITION		DIFFERENCES				RANGES		Mean Tide Level
		Latitude	Longitude	Time		Height		Mean	Diurnal	
				High Water	Low Water	High Water	Low Water			
		North	West	h m	h m	ft	ft	ft	ft	ft
	Rosario Strait, etc.			on Port Townsend, p.128						
1203	San Juan Channel Richardson, Lopez Island	48° 26.8'	122° 54.0'	–0 27	–0 12	*0.85	*0.84	4.55	7.17	4.36
1205	Shaw Island, Ferry Terminal, Harney Channel . .	48° 35.1'	122° 55.7'	+0 31	+0 56	*0.99	*0.99	4.40	7.63	4.73
1207	Friday Harbor, San Juan Island	48° 32.8'	123° 00.6'	+0 33	+0 51	*0.91	*0.92	4.82	7.76	4.70

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Tides at Difference Stations

- Friday Harbor, 12/1/05
  - Same HW "differences" apply to HHW & LHW
  - Same LW "differences" apply to HLW & LLW
  - Differences same each year
    - May be changed after further research

Tidal Stage	Port Townsend Time (PST)	Port Townsend Height (ft.)	Time DIfference (min.)	Height Difference	Friday Harbor Time (PST)	Friday Harbor Height (ft.)
HHW	0528	8.9	+ 0:33	x 0.91	0601	8.1
HLW	0924	7.4	+ 0:51	x 0.92	1015	6.8
LHW	1356	8.7	+ 0:33	x 0.91	1429	7.9
LLW	2140	-2.6	+ 0:51	x 0.92	2231	-2.4

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Tidal Current Prediction Example

- San Juan Channel 12/05
  - Nearest current reference station to Friday Harbor
  - Predicted times of slack current in column 1
    - Military (24-hour) time
    - Local Standard Time
      - Convert to Daylight Time when needed
  - Slacks are not the same
    - *Before ebb
    - *Before flood

San Juan Channel (south entrance), Washington, 2005
F–Flood, Dir. 010° True   E–Ebb, Dir. 180° True

December

	Slack	Maximum		Slack	Maximum	
	h m	h m	knots	h m	h m	knots
1 Th	*0526	0122	4.3F	16 F	0213	4.2F
	*1107	0758	2.2E		0623 0902	2.0E
●	*1511	1309	1.3F		1216 1353	0.8F
	*2236	1916	3.9E		1542 1955	3.4E
					2318	
2 F	0612	0206	4.6F	17 Sa	0253	4.1F
	1202	0843	2.2E		0701 0938	1.9E
	1548	1356	1.1F		1308 1439	0.6F
	2316	1957	3.9E		1617 2030	3.1E
					2353	
3 Sa	0659	0254	4.6F	18 Su	0333	3.9F
	1302	0929	2.2E		0738 1016	1.9E
	1631	1448	0.9F		1402 1527	0.5F
		2041	3.7E		1657 2107	2.8E

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Tidal Current Prediction Example

- San Juan Channel 12/05
  - Predicted times of maximum current in column 2
    - Military (24-hour) time
    - Local Standard Time
      - Convert to Daylight Time when needed
  - Predicted speeds of maximum current in column 3
    - Knots = nautical miles/hr
    - F= flood, E = ebb

San Juan Channel (south entrance), Washington, 2005
F–Flood, Dir. 010° True   E–Ebb, Dir. 180° True

December

	Slack	Maximum		Slack	Maximum	
	h m	h m	knots	h m	h m	knots
1 Th	*0526	0122	4.3F	16 F	0213	4.2F
	*1107	0758	2.2E		0623 0902	2.0E
●	*1511	1309	1.3F		1216 1353	0.8F
	*2236	1916	3.9E		1542 1955	3.4E
					2318	
2 F	0612	0206	4.6F	17 Sa	0253	4.1F
	1202	0843	2.2E		0701 0938	1.9E
	1548	1356	1.1F		1308 1439	0.6F
	2316	1957	3.9E		1617 2030	3.1E
					2353	
3 Sa	0659	0254	4.6F	18 Su	0333	3.9F
	1302	0929	2.2E		0738 1016	1.9E
	1631	1448	0.9F		1402 1527	0.5F
		2041	3.7E		1657 2107	2.8E

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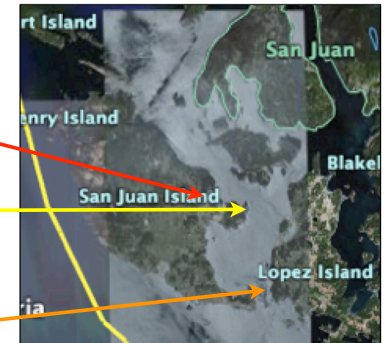# Tidal Current Prediction Example

- Port Townsend, Dec. 2005
  - Spring currents faster & neap currents weaker
    - New moon & quarter moons

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Tidal Prediction Scenario

- SCUBA diving fatality July 1995
  - Friday Harbor (San Juan Island)
  - Turn Rock Light (nearest prediction to site of accident)
  - San Juan Channel reference station

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Currents at Difference Stations

- Turn Rock Light (1.9 mi. NW of)
  - Time difference for slack before flood
  - Time difference for slack before ebb
  - Predicted reference time + difference = predicted local time
    - Slack before ebb 0526 + 0:20 minutes = 0546

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Currents at Difference Stations

- Turn Rock Light (1.9 mi. NW of)
  - Time difference for maximum flood
  - Time difference for maximum ebb
  - Predicted reference time + difference = predicted local time
    - Maximum ebb 1916 - 0:01 minutes = 1915

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Currents at Difference Stations

- Turn Rock Light (1.9 mi. NW of)
  - Speed ratio for maximum ebb
  - Speed ratio for maximum flood
  - Predicted reference speed x speed ratio = predicted local speed
    - Maximum ebb @ 1915 -3.9 E x 0.5 = - 1.95 kt

	Slack	Maximum	
	h m	h m	knots
1 Th	0526	0122	4.3F
	1107	0758	2.2E
	1511	1309	1.3F
	2236	1916	3.9E

PLACE	Meter Depth	POSITION		TIME DIFFERENCES				SPEED RATIOS	
		Latitude	Longitude	Min. before Flood	Flood	Min. before Ebb	Ebb	Flood	Ebb
SAN JUAN CHANNEL				on San Juan Channel, p.60					
Cattle Point, 1.2 miles southeast of		48° 26.03'	122° 56.82'	+0 11	-0 20	+0 34	-0 01	0.3	0.9
SAN JUAN CHANNEL (south entrance)		48° 27.68'	122° 57.05'	Daily predictions					
Kings Point, Lopez Island, 1 mile NNW of ...		48° 29.00'	122° 57.35'	+0 51	-0 07	+0 27	+0 36	0.6	0.5
Pear Point, 1.1 miles east of		48° 30.68'	122° 57.17'	+0 40	+1 09	-0 10	+1 01	0.4	0.5
Turn Rock Light, 1.9 miles northwest of		48° 33.40'	122° 59.90'	+1 19	+1 22	+0 20	-0 01	0.4	0.5
Crane Island, south of Wasp Passage		48° 35.37'	122° 58.92'	-0 10	+0 35	+0 29	+0 07		

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Currents at Difference Station

- Turn Rock Light (1.9 mi MW), 12/1/05

Tidal Stage	San Juan Channel Time (PST)	San Juan Channel Speed (kt)	Time DIfference (min.)	Speed Ratio	Turn Rock Time (PST)	Turn Rock Speed (kt)
Flood	0122	+4.3	+ 1:22	x 0.4	0244	+1.72
Slack <Ebb	0526	0	+ 0:20	-	0546	0
Ebb	0758	-2.2	- 0:01	x 0.5	0757	-1.1
Slack <Flood	1107	0	+ 1:19	-	1226	0
Flood	1309	+1.3	+ 1:22	x 0.4	1431	+0.52
Slack <Ebb	1511	0	+ 0:20	-	1531	0
Ebb	1916	-3.9	- 0:01	x 0.5	1915	-1.95
Slack <Flood	2236	0	+ 1:19	-	2355	0

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Compare Heights vs. Currents

- Friday Harbor vs. Turn Rock Light, 12/1/05
- Lesson:
  - Don't dive using height tables!
  - H & L may be 2+ hours off

Tidal Stage	Friday Harbor Time (PST)	Friday Harbor Height (ft.)
HHW	0601	8.1
HLW	1015	6.8
LHW	1429	7.9
LLW	2231	-2.4

Tidal Stage	Turn Rock Time (PST)	Turn Rock Speed (kt)
Flood	0244	+1.72
Slack <Ebb	0546	0
Ebb	0757	-1.1
Slack <Flood	1226	0
Flood	1431	+0.52
Slack <Ebb	1531	0
Ebb	1915	-1.95
Slack <Flood	2355	0

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Compare Heights vs. Currents

- Friday Harbor vs. Turn Rock Light, 12/1/05
  - H & L water do not match well with slacks
  - Typical of narrow channels with strong currents

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