Real Time Data Management: Challenges and Solutions

The Automatic Data Retrieval System (ADRS)

History and Overview

1986 - 2007

Newfoundland Labrador
Department of Environment and Conservation
Water Resources Management Division

Definitions

- Real Time
  - "*Occurring immediately. For example, real-time operating systems are systems that respond to input immediately. They are used for tasks where the computer must react to a steady flow of new information without interruption. Most general-purpose operating systems are not real-time because they can take a few seconds, or even minutes, to react*."
- *Near* Real Time
  - Measurements every hour, transmitted every three hours

Real Time Water Quality

- One Station with 7 WQ parameters + Stage with hourly measurements
  = 8 x 24 = 192 measurements per day
  = 192 x 30 = 5,760 measurements per month
  = 192 x 365 = 70,080 measurements per year

- Provincial network has 16 stations
  = 16 x 70,080 = 1,121,280 measurements per year

- Almost double the data volume of our existing 90 station hydrometric network.

Real Time Data Management

- Province has been doing real time data collection and management since 1986
- Originally for hydrometric data
  - Water level and flow data for flood forecasting, hydropower generation and reservoir regulation
- Added climate sensors in early 1990's
- Added WQ in 2002
- System is called "The Automatic Data Retrieval System (ADRS)"

Overview

- **Partnerships are critical to the success of this program**
  - Federal – Provincial governments
  - Among Provincial government agencies
    - Newfoundland & Labrador Hydro
  - Private sector
    - Hydropower and mining companies
  - Partnerships are not always financial
- Other users include:
  - Environmental groups
  - Recreational water users (fisherman, kayakers, etc)

Overview

- Instruments are connected to dataloggers
- Dataloggers are connected to transmitters
  - Package is referred to a Data Collection Platform (DCP)
  - Each transmitter has a unique identifier (PLID) such as 4816C238
- Valcom Environmental Data Acquisition System II (VEDAS II)
  - Used for most of our RTWQ stations

Overview

GOES Satellite

Normal Transmission
- every 3 hours, 3 data points per sensor

High Rate Transmission
- every hour

Immediately

Regular Intervals

National Environmental Satellite Data Information System (NESDIS)
- Operated by NOAA, Maryland, USA

New graphs every 3 hours

Government internet Web Server

- Users access using Web Browser to view graphs

- Hydropower, recreational, research, academia, D.F.O., Voisey's Bay, Provincial and Federal Departments, NGOs, consultants.

Installed Sensor Types

Water Quality
- pH
- Turbidity
- Dissolved Oxygen
- Total Dissolved Solids
- Conductivity
- Percent Saturation
- Water Temperature

Hydrometric
- Stage
- Flow

Climate
- Air Temperature
- Relative Humidity
- Air Pressure
- Wind Speed
- Wind Direction

User with a computer and internet access

GOES Satellite Network

- National Oceanic and Atmospheric Administration's (NOAA) Satellite and Information Service

- "*NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) is dedicated to providing timely access to global environmental data from satellites and other sources*"
  - "*16 meteorological satellites in 3 separate constellations*"

GOES Satellite Network

- Two satellites: GOES-East and GOES-West
- Use of these satellites is covered under national agreements and has no end-user access fees
- GOES program is very stable and has built-in reserves

Backup satellites

Active Spacecraft and Operational Status

Spacecraft	Operational Status	Status
GOES 8	Decommissioned	RED
GOES 9	Backup	YELLOW
GOES 10	Standby/Drifting	GREEN
GOES 11	Operational West	GREEN
GOES 12	Operational East	GREEN

GOES Satellite Network

- These satellites are multi-purpose. Roles include:
  - Weather imagery (visible, infrared, water vapor, etc)
  - Data Collection System (DCS)
  - "*The GOES Data Collection System (DCS) is a relay system used to collect information from earth-based platforms. These platforms transmit an electronic signal, containing the environmental data observed by the sensors on the platform, at predefined wavelengths and times. The transponder on board the satellite detects this signal, then rebroadcasts it so that it can be picked up by the ground equipment at the Wallops Command and Data Acquisition (CDA) station, in Wallops Island, Virginia*."

GOES Satellite Network

- DCS is widely used for:
  - Hydrometric stations
  - Climate stations
  - Seismic stations
  - Marine data buoys
- Use of the GOES DCS system has many advantages:
  - "*A single point of collection for the network*
  - *Stations can be placed in remote locations and left to operate with minimal intervention*
  - *Allows for more frequent and more geographically complete environmental monitoring than normally possible*"

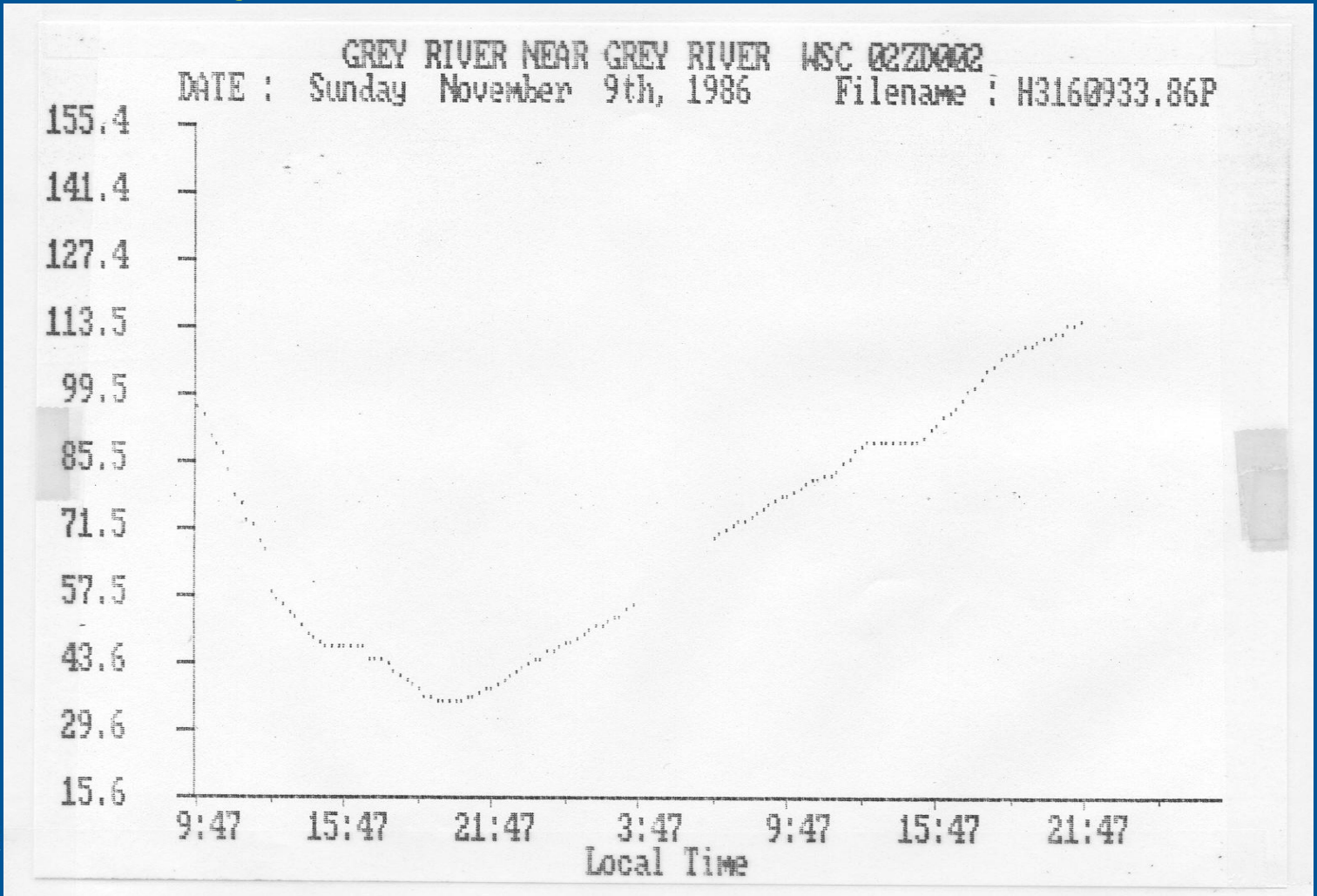
ADRS History – Ver 1.0

- Process - only current data, no history

```
Station Name  - GREY RIVER NEAR GREY RIVER  WSC 02ZD002
Platform Id   - 4816D14E
Flow Table    - \TABLES\02ZD002.TAB
Filename      - H3160933.86

Sunday  November  9th, 1986              Julian(313)
Greenwich Time = 16:17:42                                  Local Time = 12:47
Levels (m)  :    2.925   2.915   2.889   2.879   2.868   2.845   2.810   2.799   2.772   2.767   2.745   2.730
Flow (m³/s) :   96.600  95.100  90.900  89.400  87.600  84.000  78.700  77.100  73.100  72.300  69.100  67.000

Greenwich Time = 19:17:42                                  Local Time = 15:47
Levels (m)  :    2.663   2.653   2.643   2.630   2.623   2.612   2.595   2.585   2.578   2.569   2.569   2.569
Flow (m³/s) :   58.000  56.700  55.500  54.000  53.100  51.800  49.800  48.600  47.900  46.900  46.900  46.900

Greenwich Time = 22:17:42                                  Local Time = 18:47
Levels (m)  :    2.569   2.573   2.573   2.569   2.548   2.548   2.544   2.537   2.525   2.518   2.512   2.503
Flow (m³/s) :   46.900  47.300  47.300  46.900  44.500  44.500  44.100  43.300  42.000  41.200  40.500  39.500

Monday  November  10th, 1986             Julian(314)
Greenwich Time = 01:17:42                                  Local Time = 21:47(PREVIOUS DAY)
Levels (m)  :    2.489   2.479   2.472   2.467   2.467   2.467   2.467   2.468   2.472   2.477   2.482   2.487
Flow (m³/s) :   38.100  37.000  36.300  35.800  35.800  35.800  35.800  35.900  36.300  36.800  37.300  37.900

Greenwich Time = 04:17:42                                  Local Time =  0:47
Levels (m)  :    2.494   2.499   2.508   2.518   2.525   2.532   2.538   2.543   2.550   2.560   2.567   2.572
Flow (m³/s) :   38.600  39.100  40.100  41.200  42.000  42.800  43.400  44.000  44.800  45.900  46.600  47.200

Greenwich Time = 07:17:42                                  Local Time =  3:47
Levels (m)  :    2.577   2.582   2.588   2.594   2.599   2.605   2.610   2.615   2.622   2.627   2.637   2.643
Flow (m³/s) :   47.700  48.300  49.000  49.700  50.300  51.000  51.600  52.200  53.000  53.600  54.800  55.500

  WARNING==> 4816D14E 314101737 ^^ADDRESS RECEIVED WITH ERROR AS: 36C2AF36
```

ADRS History – Ver 1.0

- Graph - only current datafile, no history, dot-matrix printer only



Newfoundland Labrador

ADRS History – Vers 2.0 – 3.0
1987 - 89

- Databases for each station (ASCII text files)
- 5 day graphs on dot-matrix printers
- Weekly and monthly summary reports
- Addition of Dial Up Bulletin Board System (BBS) for distribution of data to partners
- New DCP types
- Intermediate steps to the development of a comprehensive system to collect multiple data types from multiple instruments.

ADRS History – Ver 4.0
1990 - Present

Average daily air temperature with Max/Min

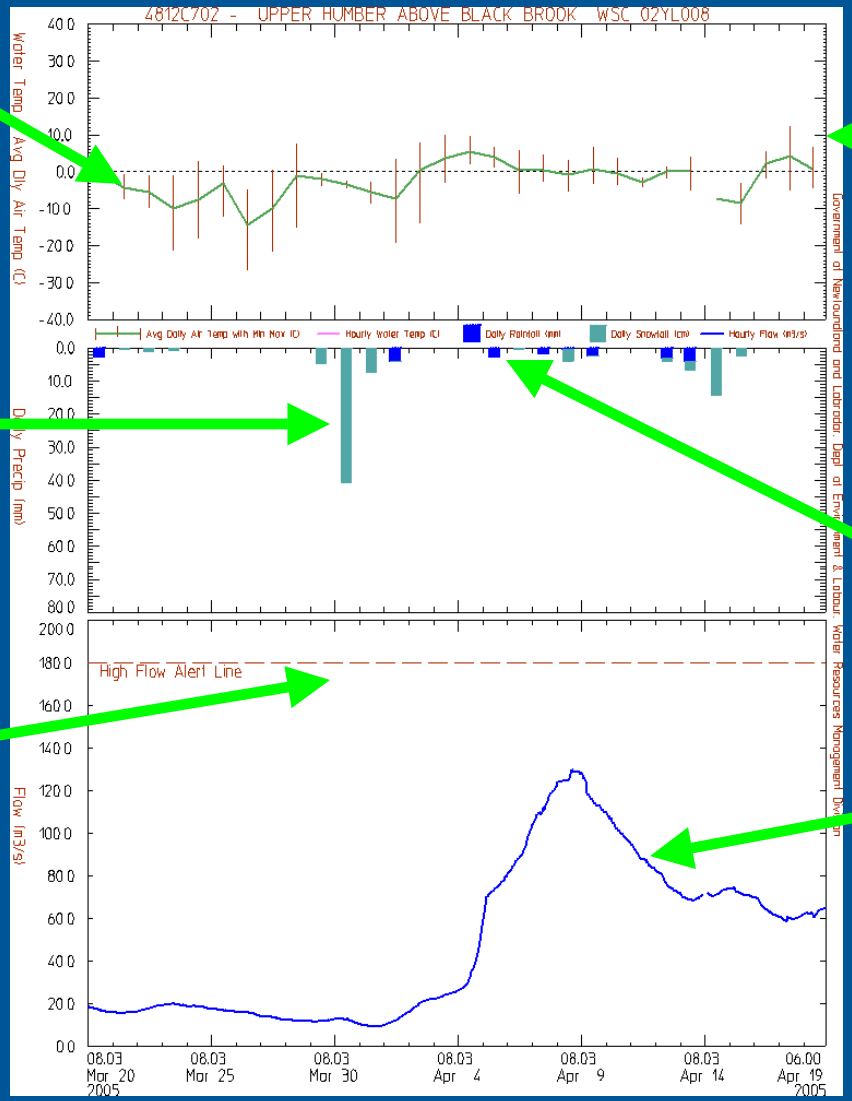
Hourly water temperature would appear here also

Daily total snowfall

Daily total rainfall

Preset high flow alert line

Hourly streamflow



Web page in 1996

Hyperlink

ADRS History – Ver 4.0
1990 - Present

Mar 2005 4812C702 - UPPER HUMBER ABOVE BLACK BROOK WSC 02YL008
Averages start at : 00:00 Prepared on : Tue. Apr 19, 2005 13:45:26

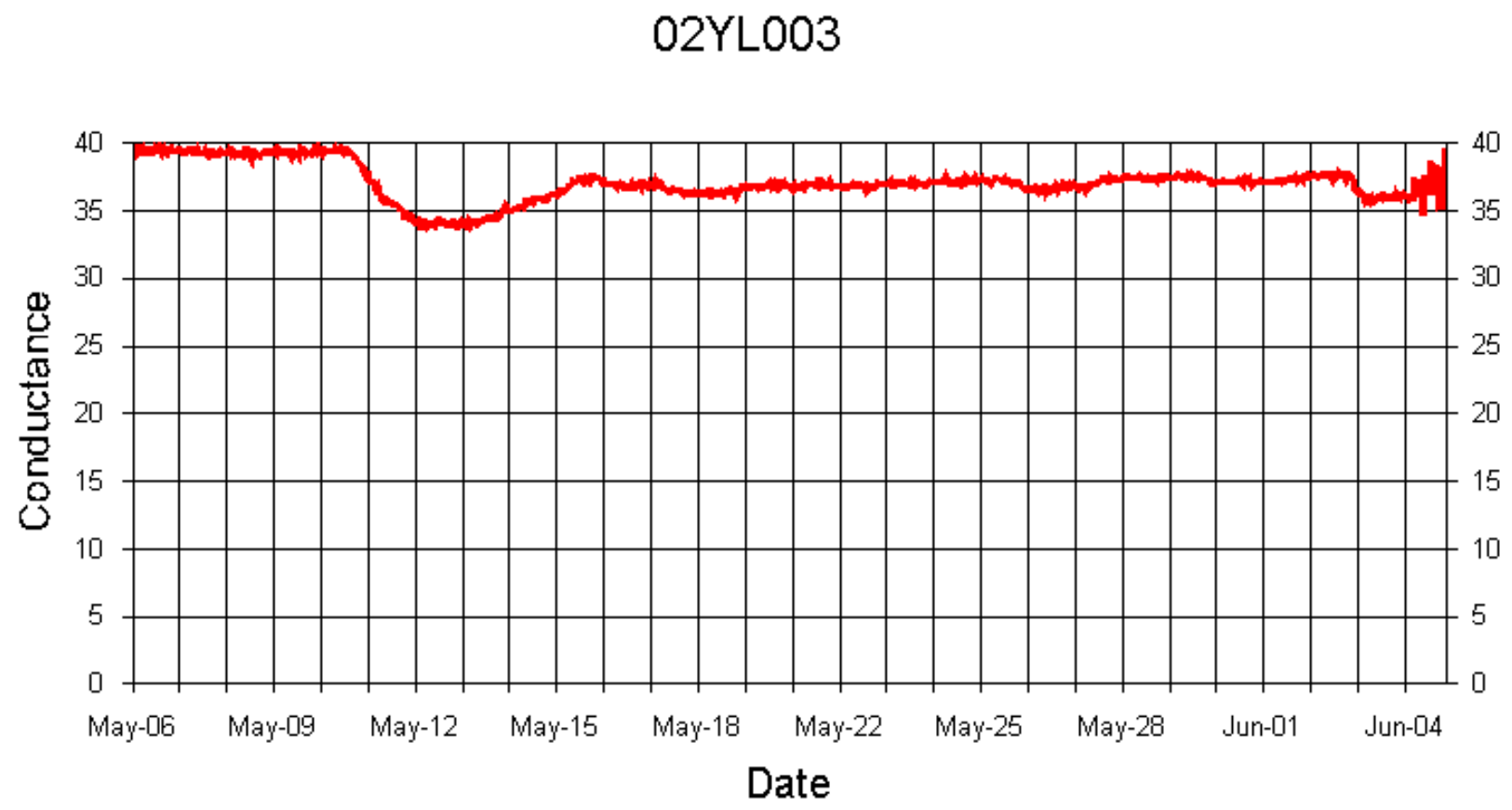
DAY	STAGE (m)	FLOW (m3/s)	TOTAL PRECIP (mm)	RAIN (mm)	SNOW (cm)	AVG ATEMP (C)	MAXI ATEMP (C)	MINI ATEMP (C)	AVG HUMID (%)	AVG WTEMP (C)	MAXI WTEMP (C)	MINI WTEMP (C)
1	1.219	40.03	2.35	0.00	2.35	-10.12	-5.80	-19.00				
2	1.251	42.51	6.13	5.41	0.72	-1.74	2.50	-6.40				
3	1.222	40.22	3.61	0.00	3.61	-2.88	-0.30	-6.50				
4	1.216	39.79	0.54	0.00	0.54	-9.48	-6.60	-12.30				
5	1.191	37.80	0.00	0.00	0.00	-10.06	-7.70	-12.40				
6	1.146	34.42	0.00	0.00	0.00	-12.46	-8.20	-23.10				
7	1.113	31.90	4.88	0.00	4.88	-10.55	-2.60	-21.60				
8	1.109	31.52	0.18	0.00	0.18	-12.17	-1.20	-25.90				
9	1.093	30.28	0.00	0.00	0.00	1.80	4.30	-2.80				
10	1.130	33.16	7.21	0.00	7.21	-6.44	0.20	-20.60				
11	1.142	34.07	0.00	0.00	0.00	-15.19	-2.80	-27.20				
12	1.094	30.40	0.00	0.00	0.00	-13.30	-3.40	-24.70				
13	1.043	26.63	0.00	0.00	0.00	-3.24	1.40	-8.30				
14	1.017	24.71	0.00	0.00	0.00	0.30	1.20	-1.80				
15	0.996	23.25	0.00	0.00	0.00	-2.06	1.20	-5.90				
16	0.966	21.11	0.55	0.00	0.55	-1.06	0.10	-2.60				
17	0.921	18.08	2.88	1.08	1.80	0.13	1.70	-1.10				
18	0.963	20.91	3.25	0.00	3.25	-1.24	0.10	-3.50				
19	0.975	21.75	0.00	0.00	0.00	-3.37	-1.60	-4.30				
20	0.925	18.30	2.71	2.71	0.00	-1.29	2.30	-4.80				
21	0.890	15.87	0.54	0.00	0.54	-2.65	-0.80	-6.20				
22	0.905	16.97	1.08	0.00	1.08	-4.82	-1.20	-7.40				
23	0.942	19.49	0.55	0.00	0.55	-6.46	-1.00	-16.40				
24	0.934	18.97	0.18	0.00	0.18	-9.28	2.90	-21.20				
25	0.911	17.36	0.00	0.00	0.00	-6.37	1.50	-17.90				
26	0.894	16.14	0.00	0.00	0.00	-8.01	-4.10	-21.50				
27	0.863	14.12	0.00	0.00	0.00	-12.63	0.30	-26.40				
28	0.834	12.38	0.00	0.00	0.00	-5.02	7.60	-19.20				
29	0.825	11.88	0.00	0.00	0.00	-2.81	-0.50	-6.10				
30	0.840	12.71	40.96	0.00	40.96	-3.02	-2.20	-4.30				
31	0.792	10.22	11.01	0.00	11.01	-4.20	-2.90	-7.00				
Avg	1.012	24.74				-5.80						
Tot			88.61	9.20	79.41							
Max	1.259	43.20					7.60					
Min	0.776	9.42						-27.20				

N.B. - Maximum and Minimum Stage and Flow values are instantaneous
- Under TOTAL PRECIP F indicates that the gauge was full and R indicates the gauge was reset

ADRS History – ADRS 5.0

- New tools - Visual Basic 6.0 and graphics toolkits
- Access to Washington via Internet
- Specifically for the Real Time Water Quality (RTWQ) system
  - Much larger number of sensors
- An intermediate step to the development of a system that incorporates hydrologic, climate and RTWQ data

ADRS History – ADRS 5.0



Last Reading: Jun-05-2006 11:50AM Conductance = 39.3

Hyperlink

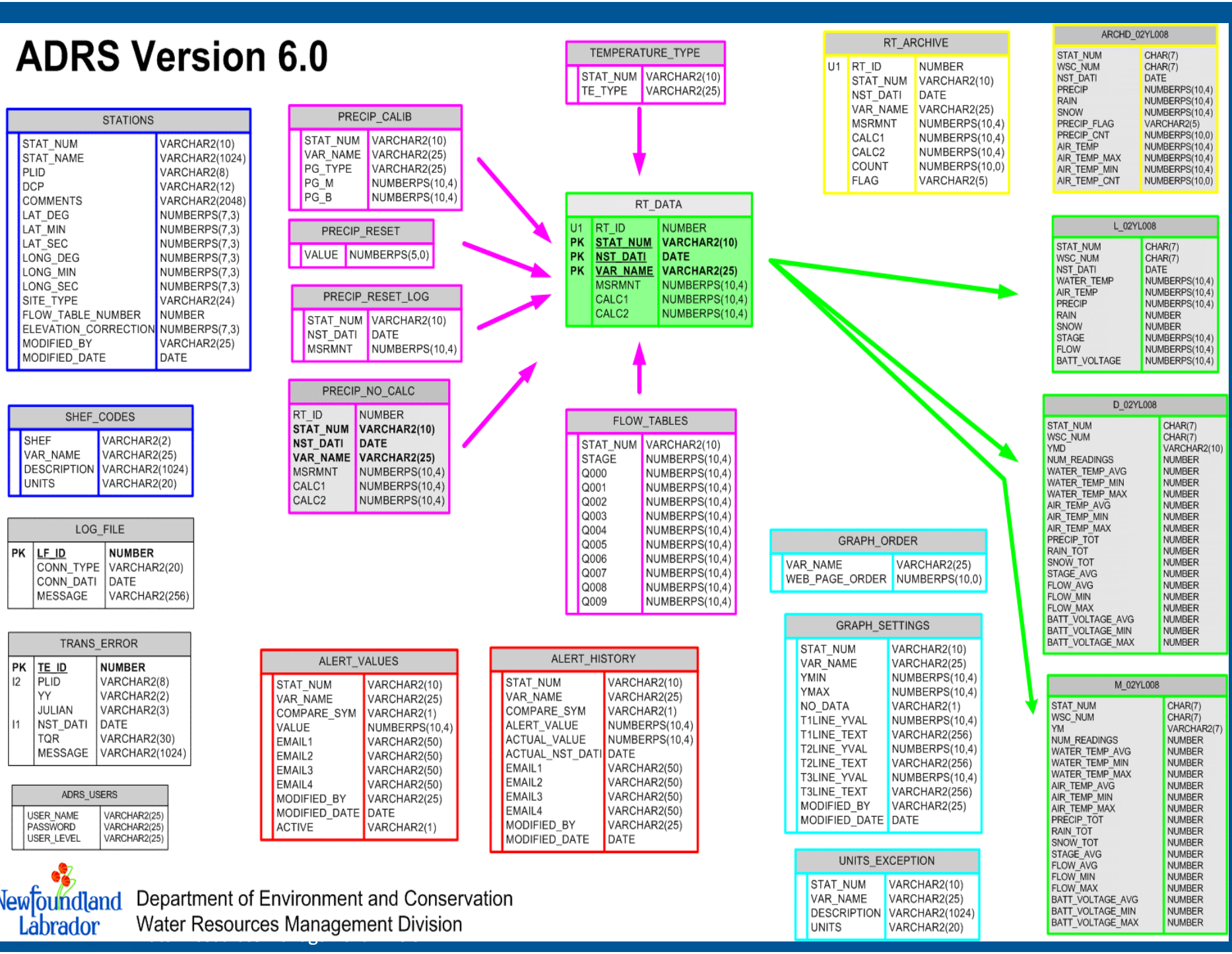
The Present - ADRS 6.0

- Captures data from all real-time stations both GOES and dial-up
- Uses Enterprise Database server (Oracle 9.2) and MS Visual Studio .Net 2003
  - Improved links to other Divisional databases and GIS
- New types of output
  - Station web pages that show summary historical data, graphs and downloadable data
- Capability for new value added-products
  - Real Time Water Quality Index
  - New types of data summaries

ADRS 6.0 - Hardware

- Database - Oracle 9.2 (with ESRI ArcSDE 9.0)
  - IBM @Server x series 345 – Intel Xeon 2.8Ghz, 1 Gb RAM – Windows Server 2000
- Intranet - Microsoft IIs Server
  - IBM @Server x series 336 Intel Xeon 3.0Ghz, 3 Gb RAM – Windows Server 2003
- Console Applications - Windows XP PC
  - Dell Optiplex GX280 P4 2.8 Ghz desktop PC – Windows XP SP2
- Internet – Government Public Web Server

ADRS Version 6.0



Newfoundland Labrador

Department of Environment and Conservation
Water Resources Management Division

ADRS 6.0 – Database Tables

RT_DATA		
U1	RT_ID	NUMBER
PK	**STAT_NUM**	**VARCHAR2(10)**
PK	**NST_DATI**	**DATE**
PK	**VAR_NAME**	**VARCHAR2(25)**
	MSRMNT	NUMBERPS(10,4)
	CALC1	NUMBERPS(10,4)
	CALC2	NUMBERPS(10,4)

CALC1 and CALC2 are variable specific

RT_ID	STAT_NUM	NST_DATI	VAR_NAME	MSRMNT	CALC1	CALC2
1436048	02YL008	17-Dec-2006 13:30:09	PRECIP	527.3565	527.3565	0.1805
1436044	02YL008	17-Dec-2006 14:30:09	AIR_TEMP	-3.8		
1436053	02YL008	17-Dec-2006 14:30:09	STAGE	0.954	21.2	
1436056	02YL008	17-Dec-2006 14:30:09	BATT_VOLTAGE	11.78		
1436047	02YL008	17-Dec-2006 14:30:09	PRECIP	529.7027	529.7027	2.3462
1436050	02YL008	17-Dec-2006 14:30:09	WATER_TEMP	-72.8		
1437377	02YL008	17-Dec-2006 18:30:10	AIR_TEMP	-5.3		
1437383	02YL008	17-Dec-2006 18:30:10	WATER_TEMP	-72.8		
1437386	02YL008	17-Dec-2006 18:30:10	STAGE	0.971	22.3	
1437380	02YL008	17-Dec-2006 18:30:10	PRECIP	531.6879	531.6879	1.9852
1437376	02YL008	17-Dec-2006 19:30:10	AIR_TEMP	-4.6		
1437382	02YL008	17-Dec-2006 19:30:10	WATER_TEMP	-72.8		
1437385	02YL008	17-Dec-2006 19:30:10	STAGE	0.975	22.6	
1437379	02YL008	17-Dec-2006 19:30:10	PRECIP	532.0489	532.0489	0.361
1437375	02YL008	17-Dec-2006 20:30:10	AIR_TEMP	-4		
1437387	02YL008	17-Dec-2006 20:30:10	BATT_VOLTAGE	11.35		
1437384	02YL008	17-Dec-2006 20:30:10	STAGE	0.977	22.7	
1437378	02YL008	17-Dec-2006 20:30:10	PRECIP	531.6879	532.0489	0
1437381	02YL008	17-Dec-2006 20:30:10	WATER_TEMP	-72.8		
1437940	02YL008	17-Dec-2006 21:30:09	AIR_TEMP	-3.9		
1437943	02YL008	17-Dec-2006 21:30:09	PRECIP	531.6879	532.0489	0
1437946	02YL008	17-Dec-2006 21:30:09	WATER_TEMP	-72.8		
1437949	02YL008	17-Dec-2006 21:30:09	STAGE	0.979	22.9	

ADRS 6.0 – Database Views

```
CREATE OR REPLACE VIEW L_02yl008 (stat_num, wsc_num, nst_dati, water_temp, air_temp, precip, rain, snow, stage, flow, batt_voltage )
AS

SELECT '02YL008' AS STAT_NUM, '02YL008' AS WSC_NUM, T.NST_DATI, V1.WATER_TEMP, V20.AIR_TEMP, V22.PRECIP,
CASE WHEN v20.air_temp >= 0 THEN v22.precip else null end as "RAIN",
CASE WHEN v20.air_temp < 0 THEN v22.precip else null end as "SNOW" ,
V40.STAGE, V40.FLOW, V50.BATT_VOLTAGE

FROM
(SELECT DISTINCT NST_DATI FROM RT_DATA WHERE STAT_NUM = '02YL008') T,
(SELECT NST_DATI, MSRMNT AS WATER_TEMP FROM RT_DATA WHERE (VAR_NAME = 'WATER_TEMP' AND STAT_NUM = '02YL008')) V1,
(SELECT NST_DATI, MSRMNT AS AIR_TEMP FROM RT_DATA WHERE (VAR_NAME = 'AIR_TEMP' AND STAT_NUM = '02YL008')) V20,
(SELECT NST_DATI, CALC2 AS PRECIP FROM RT_DATA WHERE (VAR_NAME = 'PRECIP' AND STAT_NUM = '02YL008')) V22,
(SELECT NST_DATI, MSRMNT AS STAGE, CALC1 AS FLOW FROM RT_DATA WHERE (VAR_NAME = 'STAGE' AND STAT_NUM = '02YL008')) V40,
(SELECT NST_DATI, MSRMNT AS BATT_VOLTAGE FROM RT_DATA WHERE (VAR_NAME = 'BATT_VOLTAGE' AND STAT_NUM = '02YL008')) V50

WHERE
(T.NST_DATI = V1.nst_dati(+)) AND
(T.NST_DATI = V20.nst_dati(+)) AND
(T.NST_DATI = V22.nst_dati(+)) AND
(T.NST_DATI = V40.nst_dati(+)) AND
(T.NST_DATI = V50.nst_dati(+))
/
```

- Line Data Views - Use Sub-queries
- Assemble all the times for all parameters on the left (T)
- Left join all the parameters (V1, V20, V22, V40, V50)

L_02YL008	
STAT_NUM	CHAR(7)
WSC_NUM	CHAR(7)
NST_DATI	DATE
WATER_TEMP	NUMBERPS(10,4)
AIR_TEMP	NUMBERPS(10,4)
PRECIP	NUMBERPS(10,4)
RAIN	NUMBER
SNOW	NUMBER
STAGE	NUMBERPS(10,4)
FLOW	NUMBERPS(10,4)
BATT_VOLTAGE	NUMBERPS(10,4)

ADRS 6.0 – Database Views

```
CREATE OR REPLACE VIEW d_02yl008 ( stat_num, wsc_num, ymd, num_readings, water_temp_avg, water_temp_min, water_temp_max,
  air_temp_avg, air_temp_min, air_temp_max, precip_tot, rain_tot, snow_tot, stage_avg, flow_avg, flow_min, flow_max,
  batt_voltage_avg, batt_voltage_min, batt_voltage_max )
AS

SELECT STAT_NUM, WSC_NUM, TO_CHAR(NST_DATI,'YYYY/MM/DD') as YMD, count(NST_DATI) AS NUM_READINGS,
ROUND(AVG(WATER_TEMP),2) AS WATER_TEMP_AVG, ROUND(MIN(WATER_TEMP),2) AS WATER_TEMP_MIN,
ROUND(MAX(WATER_TEMP),2) AS WATER_TEMP_MAX , ROUND(AVG(AIR_TEMP),2) AS AIR_TEMP_AVG,
ROUND(MIN(AIR_TEMP),2) AS AIR_TEMP_MIN, ROUND(MAX(AIR_TEMP),2) AS AIR_TEMP_MAX , ROUND(SUM(PRECIP),2) AS PRECIP_TOT,
ROUND(SUM(RAIN),2) AS RAIN_TOT, ROUND(SUM(SNOW),2) AS SNOW_TOT , ROUND(AVG(STAGE),2) AS STAGE_AVG,
ROUND(AVG(FLOW),2) AS FLOW_AVG, ROUND(MIN(FLOW),2) AS FLOW_MIN, ROUND(MAX(FLOW),2) AS FLOW_MAX ,
ROUND(AVG(BATT_VOLTAGE),2) AS BATT_VOLTAGE_AVG, ROUND(MIN(BATT_VOLTAGE),2) AS BATT_VOLTAGE_MIN,
ROUND(MAX(BATT_VOLTAGE),2) AS BATT_VOLTAGE_MAX

FROM
L_02YL008 GROUP BY TO_CHAR(NST_DATI,'YYYY/MM/DD')
/
```

- Daily and Monthly views are based on the Line data views
- Includes basic summary statistics (Avg, Min, Max,etc)

D_02YL008	
STAT_NUM	CHAR(7)
WSC_NUM	CHAR(7)
YMD	VARCHAR2(10)
NUM_READINGS	NUMBER
WATER_TEMP_AVG	NUMBER
WATER_TEMP_MIN	NUMBER
WATER_TEMP_MAX	NUMBER
AIR_TEMP_AVG	NUMBER
AIR_TEMP_MIN	NUMBER
AIR_TEMP_MAX	NUMBER
PRECIP_TOT	NUMBER
RAIN_TOT	NUMBER
SNOW_TOT	NUMBER
STAGE_AVG	NUMBER
FLOW_AVG	NUMBER
FLOW_MIN	NUMBER
FLOW_MAX	NUMBER
BATT_VOLTAGE_AVG	NUMBER
BATT_VOLTAGE_MIN	NUMBER
BATT_VOLTAGE_MAX	NUMBER

ADRS 6.0 – Web Output

- Page creation:
  - Graphs and ordering on web page is dictated by settings in Oracle database tables
  - Eliminates the need to create and manage 90+ web pages
- Web pages are not interactive and this eliminates the requirement for:
  - a complex interactive application and corresponding server resources
  - detailed security design and review
- This greatly reduces costs and development time
- End product meets the needs of majority of users

ADRS 6.0 – Application and Data Management

- The ADRS Management Console is an Internal application that allows users to:
  - View system and stations status
  - View retrieval history, transmission errors and alert email history
  - View and edit configuration files for stations, graphs , Shef codes, alerts
  - Update station database views
  - Browse, query and graph station data
  - Create multi-station graphs

ADRS Management Console

- Broken down into 3 Categories
- Operations
  - System Status
    - Gives a snapshot of the database totals
    - When the graphs, xml and excel files were last updated
    - The date and time of the last Telnet retrieval, and the latest record
    - Database Summary – Total errors, stations and graphs
    - Lists all the station parameters that haven't updated in the last 24 hours

ADRS Management Console

- Operations (Continued)
- Station Status
  - Gives a snapshot of the all the stations and parameters
    - shows when each individual parameter was last updated
  - Retrieval History
    - Shows the log file that lists Telnet retrievals and status
  - Station Transmission Errors
    - Shows the transmission errors from the last 14 days
  - Alert Notification History
    - Shows historical email alerts
      - Provides information such as the station, sent to, the message and the date it was emailed

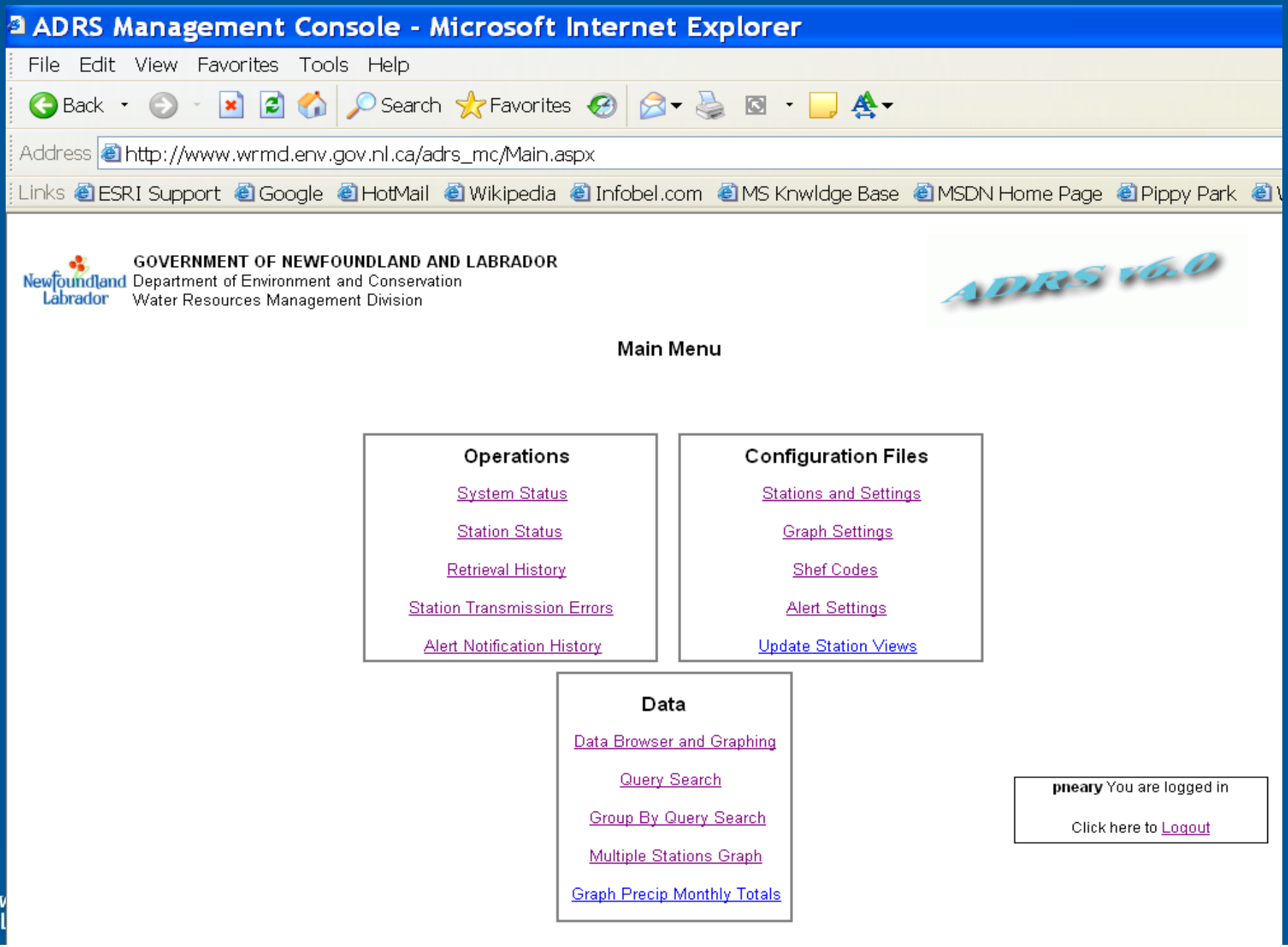
ADRS Management Console

- Configuration Files
  - Stations and Settings
    - Pick station and edit the station settings
  - Graph Settings
    - Add a graph or edit the settings of a graph for a station
  - Shef Codes
    - Add or edit SHEF codes
  - Alert Settings
    - Add or edit email Alerts
  - Update Station Views
    - Pick a Station and update the database Line, Daily and Monthly views related to that station

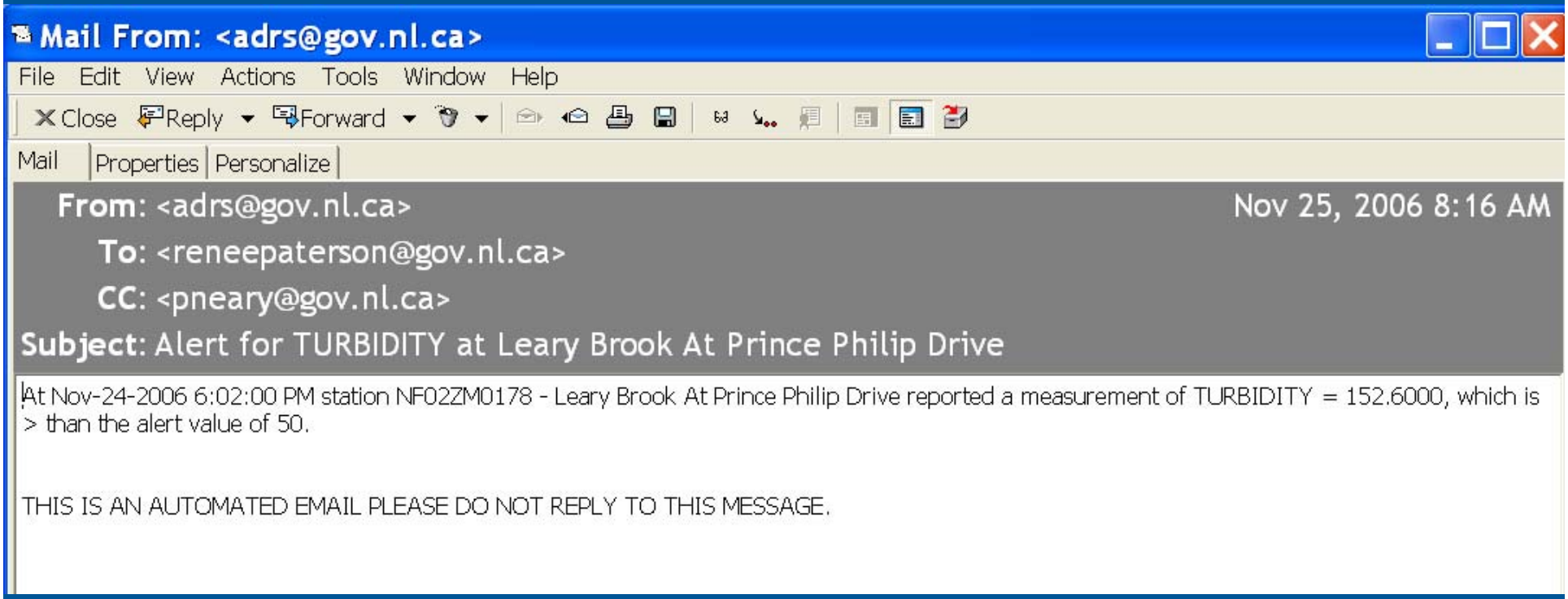
ADRS Management Console

- Data
  - Data Browser and Graphing
    - Select a station and search by Line, Daily, Monthly or archive data.
    - Select a date range or day
    - Graph individual parameters based on your selected data
    - Export information to Excel
  - Query Search
    - Query any available table or view using the query tool
  - Group By Query Search
    - Calculates averages or counts from views
  - Multiple Stations Graph
    - Graph one parameter for multiple stations for a specified date range
  - Graph Precipitation Monthly Totals
    - Creates stacked bar graphs (rain/snow) from monthly totals for stations

ADRS Management Console



Sample Warning Email



Demonstration

- Public
  - http://www.env.gov.nl.ca/wrmd/RTWQ/RTWQ.asp
- Internal
  - http://www.wrmd.env.gov.nl.ca/adrs_mc/default.aspx
- Google Earth
  - http://www.env.gov.nl.ca/Env/env/waterres/GIS/Google/WRMD_Stations.kmz

ADRS 6.0 - The Future

- HYDAT Data Summaries
  - Comparison of real-time data to percentiles
- QA/QC of Archive Climate data from DLP Agreement
- Linkage to GIS for advanced products
- Integration of advanced RTWQ functionality
  - Inventory
  - Database of “Events”
  - Advanced statistics
  - WQI

Thank You!

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Water Resources Management Division
Home Page

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