Graph formating

In[1]:=
```
thinn = AbsoluteThickness[.5];
medum = AbsoluteThickness[1.];
thick = AbsoluteThickness[1.5];
black = GrayLevel[0];
BGray = GrayLevel[0.3];
WGray = GrayLevel[0.6];
SetOptions[Plot, PlotStyle → {{thinn, Black}, {thinn, Black}, {thinn, Black}},
  PlotPoints → 40, ImageSize → 360,
  FrameStyle -> medum, AxesStyle -> medum,
  BaseStyle -> {FontFamily -> "Helvetica", FontSlant → Plain, FontSize → 12}];
SetOptions[ListPlot, PlotStyle → Black, AxesStyle -> medum,
  PlotStyle → medum, ImageSize → 384,
  BaseStyle -> {FontFamily -> "Helvetica", FontSlant -> "Plain", FontSize → 12}];
SetOptions[ParametricPlot, PlotStyle →
   {{thinn, Black}, {thinn, Black}, {thinn, Black}}, PlotPoints → 40,
  FrameStyle -> medum, AxesStyle -> medum, PlotStyle → medum,
  BaseStyle -> {FontFamily -> "Helvetica", FontSlant -> "Plain", FontSize → 12}];
SetOptions[Graphics, BaseStyle ->
   {FontFamily -> "Helvetica", FontSlant -> "Plain", FontSize → 12}];
```

Chapter 3 "Drawing from a Reservior" model

dynamic parameters

In[11]:=
```
T = 40;
d = .06;
g = .01;
```

benefits (build demand using parameters from Chap 2 and integrate under it)

mblater is for evaluating pricing after all else is completed

In[14]:=
```
q0 = 35 000;
p0 = 3;
elast = -1 / 2;
c = q0 / p0^elast;
wlog = (1 + g)^(t - 1) * c * p^elast;
mb = p /. Flatten[Simplify[Solve[w == %, p]]];
mblater = mb /. w → ww;
Assuming[{W > 100}, tb = ∫_100^W mb dw];
```

costs

In[22]:=
```
tc = 50 000 + 1.95 * W + 0.000015 * W^2;
mclater = D[tc, W] /. W → ww;
```

hydrologics

In[24]:=
```
initialstored = 160 000.;
annualflow = 27 000;
```

develop work matrix

In[26]:=
```
wvector = Prepend[Array[w, T - 1], w0];
work = Table[1., {t, T}, {j, 8}];
work[[1, 1]] = 0;
Do[work[[t + 1, 1]] = t, {t, T - 1}]
Do[work[[t, 2]] = W /. Flatten[Solve[D[(tb - tc), W] == 0, W, Reals]], {t, 1, T}]
Do[work[[t, 3]] = wvector[[t]], {t, T}]
Do[work[[t, 4]] = (tb - tc) /. W → work[[t, 3]], {t, T}]
Do[work[[t, 5]] = work[[t, 4]] / (1 + d) ^ (t - 1), {t, T}]
work[[1, 6]] = initialstored + annualflow;
Do[work[[t, 6]] = work[[t - 1, 6]] + annualflow - work[[t - 1, 3]], {t, 2, T}]
work[[1, 7]] = initialstored + annualflow;
work[[1, 8]] = Min[work[[1, 2]], work[[1, 7]]];
Do[{work[[t, 7]] = work[[t - 1, 7]] + annualflow - work[[t - 1, 8]],
  work[[t, 8]] = Min[work[[t, 2]], work[[t, 7]]]}, {t, 2, T}]
rslts = TableForm[Prepend[work, {"Period", "MNB=0@", "w", "NBs",
     "PV(NBs)", "Reserv@Start", "MyopicReserv", "MyopicUse"}]];
Dual = D[work[[1, 4]], w0];
```

Solve::ratnz : Solve was unable to solve the system with inexact coefficients. The answer was obtained by solving a corresponding exact system and numericizing the result. ≫

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General::stop : Further output of Solve::ratnz will be suppressed during this calculation. ≫

develop NPV and single constraint

In[41]:=
```
npv = Apply[Plus, Part[Transpose[work], 5]];
```

The Maximize command employed later requires a tedious list of positivity constraints for water use in every period. Below, string commands are employed to build this list of constraints to fit whatever T is and avoid typing them all out when the Maximize command is used.

In[42]:=
```
summeduse = Apply[Plus, wvector];
excesswater = initialstored + T * annualflow - summeduse;
positivity = ToString[""];
For[i = 1, i < T, i++,
 positivity = StringJoin[positivity, "&&w[", ToString[i], "]≥0"]]
allconstraints = StringJoin["excesswater==0&&w0>0", ToExpression["positivity"]];
```

Max NPV

In[47]:=
```
answer = Maximize[{npv, ToExpression[allconstraints]}, wvector]
```

Out[47]=
$$\{7.61448 \times 10^8, \{w_0 \to 31\,573.3, w[1] \to 31\,673.4, w[2] \to 31\,765.8, w[3] \to 31\,849.9,$$
$$w[4] \to 31\,925.8, w[5] \to 31\,992.9, w[6] \to 32\,050.8, w[7] \to 32\,099.3, w[8] \to 32\,137.6,$$
$$w[9] \to 32\,166., w[10] \to 32\,184.1, w[11] \to 32\,191.4, w[12] \to 32\,187.5, w[13] \to 32\,172.6,$$
$$w[14] \to 32\,145.9, w[15] \to 32\,107.4, w[16] \to 32\,057., w[17] \to 31\,994.3,$$
$$w[18] \to 31\,919.9, w[19] \to 31\,832.5, w[20] \to 31\,733., w[21] \to 31\,620.9, w[22] \to 31\,497.,$$
$$w[23] \to 31\,360.1, w[24] \to 31\,211.3, w[25] \to 31\,049.6, w[26] \to 30\,876.5,$$
$$w[27] \to 30\,690.7, w[28] \to 30\,494., w[29] \to 30\,286.1, w[30] \to 30\,066.6, w[31] \to 29\,836.,$$
$$w[32] \to 29\,596., w[33] \to 29\,344.9, w[34] \to 29\,085.4, w[35] \to 28\,816.2,$$
$$w[36] \to 28\,538.2, w[37] \to 28\,252.7, w[38] \to 27\,959., w[39] \to 27\,658.4\}\}$$

incorporate optimal use schedule into "work" matrix and prepare for printing/plotting

check to see how much water is used

In[53]:=
```
summeduse
```

Out[53]=
$$1.24 \times 10^6$$

extract plottable vectors from matrix

In[54]:=
```
myopicUse = Transpose[Join[Take[Transpose[work], 1], Take[Transpose[work], {8, 8}]]]
```

Out[54]=
```
{{0, 35 000.}, {1, 35 297.5}, {2, 35 597.3}, {3, 35 899.4}, {4, 36 203.9},
 {5, 36 510.6}, {6, 36 819.7}, {7, 37 131.2}, {8, 37 445.}, {9, 37 761.2},
 {10, 38 079.8}, {11, 38 400.9}, {12, 38 724.4}, {13, 39 050.3}, {14, 39 378.7},
 {15, 34 700.1}, {16, 27 000.}, {17, 27 000.}, {18, 27 000.}, {19, 27 000.},
 {20, 27 000.}, {21, 27 000.}, {22, 27 000.}, {23, 27 000.}, {24, 27 000.},
 {25, 27 000.}, {26, 27 000.}, {27, 27 000.}, {28, 27 000.}, {29, 27 000.},
 {30, 27 000.}, {31, 27 000.}, {32, 27 000.}, {33, 27 000.}, {34, 27 000.},
 {35, 27 000.}, {36, 27 000.}, {37, 27 000.}, {38, 27 000.}, {39, 27 000.}}
```

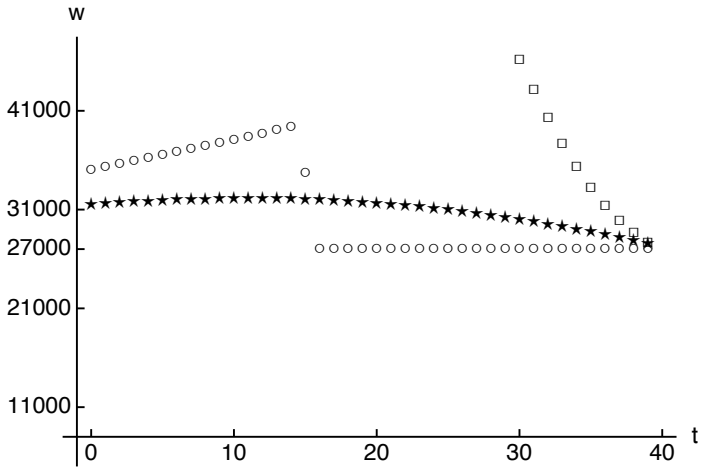
In[55]:=
```
optUse = Transpose[Join[Take[Transpose[work], 1], Take[Transpose[work], {3, 3}]]];
```

In[56]:=
```
optreservoirlevel =
  Transpose[Join[Take[Transpose[work], 1], Take[Transpose[work], {6, 6}]]];
```

generate plot

In[57]:=
```
pl36 = ListPlot[{optreservoirlevel, myopicUse, optUse},
  AxesLabel → {"t", "w"}, PlotRange → {{-2, T + 1}, {5000, 48 500}},
  AxesOrigin → {-1, 8000},
  PlotStyle -> Black,
  PlotMarkers → {□, ○, ★},
  Ticks → {{0, 10, 20, 30, 40},
    {{11 000, "11000"}, {21 000, "21000"},
     {27 000, "27000"}, {31 000, "31000"}, {41 000, "41000"}}},
  ImageSize → 360, AspectRatio → 0.7]
```

Out[57]=



In[58]:=

Price planning

In[59]:=
```
pricing = Table[1., {t, T}, {j, 4}];
pricing[[1, 1]] = 0;
Do[pricing[[t + 1, 1]] = t, {t, T - 1}]
Do[pricing[[t, 2]] = (mblater - mclater) /. ww → optUse[[t, 2]], {t, 1, T}]
Do[pricing[[t, 3]] = mblater /. ww → optUse[[t, 2]], {t, 1, T}]
Do[pricing[[t, 4]] = mblater /. ww → myopicUse[[t, 2]], {t, 1, T}]

TableForm[Prepend[pricing, {"Period", "muc", "p*", "MyopicP"}]]
```

Out[65]//TableForm=

Period	muc	p*	MyopicP
0	0.789326	3.68653	3.
1	0.836698	3.7369	3.00893
2	0.886885	3.78986	3.01792
3	0.940152	3.84565	3.02698
4	0.996545	3.90432	3.03612
5	1.05632	3.96611	3.04532
6	1.1197	4.03123	3.05459
7	1.18686	4.09983	3.06393
8	1.25815	4.17228	3.07335
9	1.33363	4.24861	3.08284
10	1.41361	4.32914	3.09239
11	1.49842	4.41416	3.10203
12	1.58835	4.50398	3.11173
13	1.68359	4.59876	3.12151
14	1.78462	4.699	3.13136
15	1.89173	4.80495	4.11374
16	2.00525	4.91696	6.93129
17	2.12561	5.03544	7.0706
18	2.25303	5.16063	7.21272
19	2.38833	5.2933	7.3577
20	2.53163	5.43362	7.50559
21	2.68358	5.58221	7.65645
22	2.84441	5.73932	7.81035
23	3.01507	5.90588	7.96733
24	3.19585	6.08219	8.12748
25	3.38773	6.26922	8.29084
26	3.59084	6.46714	8.45749
27	3.80654	6.67726	8.62748
28	4.03482	6.89964	8.80089
29	4.27671	7.13529	8.97779
30	4.53335	7.38535	9.15824
31	4.80564	7.65072	9.34233
32	5.09369	7.93157	9.53011
33	5.3997	8.23005	9.72166
34	5.72337	8.54593	9.91707
35	6.06686	8.88135	10.1164
36	6.4311	9.23725	10.3197
37	6.81673	9.61431	10.5272
38	7.22594	10.0147	10.7388
39	7.65951	10.4393	10.9546

In[66]:=
```
muc = Transpose[Join[Take[Transpose[pricing], 1], Take[Transpose[pricing], {2, 2}]]];
optP = Transpose[
  Join[Take[Transpose[pricing], 1], Take[Transpose[pricing], {3, 3}]]]; myopticP =
 Transpose[Join[Take[Transpose[pricing], 1], Take[Transpose[pricing], {4, 4}]]];
```

In[67]:=
```
pl37 = ListPlot[{muc, optP, myopticP},
  AxesLabel → {"t", "$"},
  PlotRange → {{-2, T + 1}, {0, 11.3}},
  AxesOrigin → {-1, 0},
  PlotStyle -> Black,
  PlotMarkers → {"δ", ⋆, ○},
  Ticks → {{0, 10, 20, 30, 40},
    {2, 4, 6, 8, 10}},
  ImageSize → 360, AspectRatio → 0.7]
```

Out[67]=