In[1]:=
```
SetDirectory[NotebookDirectory[]];
```

In[2]:=
```
(* Find flow of cost corresponding to a given PV using 3% and 20 years,
then discount that flow using 4% and 30 years. *)
change320to430[claimedPV_] :=
 Sum[(claimedPV / Sum[1 / (1 + .03)^t, {t, 1, 20}]) / (1 + .04)^t, {t, 1, 30}]
powercostadjustment[claimedPV_] := -claimedPV + change320to430[claimedPV]
```

In[4]:=
```
(* Each reservoir has a capacity, "AF" for acre-feet, and a cost. *)
(* "Position" refers to position in the data structure *)
AFPosition = 1; CostPosition = 2;

(* RESERVOIRS *)
(* Fielding Reservoir *)
Fielding0 = {0, 0};
FieldingPosition = 1; (* Fielding is the first reservoir in the data structure. *)
Fielding40 = {40000, 137705000};
Fielding70 = {70000, 169527000};
(* Whites Valley Reservoir *)
WhitesV0 = {0, 0};  WhitesVPosition = 2 ;
WhitesV170 = {170000, 360672000};
WhitesV305 = {305000, 381913000};
WhitesV309 = {309000, 384842000};
WhitesV319 = {319000, 385763000};
WhitesV330 = {330000, 389651000};
WhitesV333 = {333000, 388140000};(* 330k vs. 333k anomalous but not by much *)
WhitesV360 = {360000, 397645000};
WhitesV400 = {400000, 414726000};
WhitesV540 = {540000, 483385000};
WhitesV610 = {610000, 533953000};
(* South Willard Reservoir *)
SWillard0 = {0, 0};  SWillardPosition = 3; SWillard = {55000, 427793000};
(* Cub River Reservoir *)
CubR0 = {0, 0};  CubRPosition = 4; CubR = {27000, 113461000};
(* Above Cutler Reservoir *)
AboveCutler0 = {0, 0};  AboveCutlerPosition = 5;
AboveCutler = {51000, 285506000};
(* Temple Fork Reservoir *)
TempleFork0 = {0, 0};  TempleForkPosition = 6;
TempleFork = {41000, 100009000};
(* PUMPS AND PIPELINES *)
FieldingPump = 187554000;
FieldingPumpAdjustment = 114196000;
(* Subtract this if Fielding but not WhitesV and not PipeFieldingCutler *)
(*  This adjustment comes from the State's scenario "I". *)
PipeFieldingWHaven = 399420000;
PipeFieldingCutlerShort = 37175000; (* with Fielding40 *)
PipeFieldingCutlerLong = 50195000; (* with Fielding70 or Fielding0 *)
(* Cache needs either PipeFieldingCutler (short or long) or one of: Cub River,
Above Cutler, Temple Fork. *)
BearRDiversion = 11686600; (* If (no Fielding) and
 (Box Elder or Weber or Jordan or (Cache and PipeFieldingCutler)) *)

(* ACRE-FEET OF WATER REQUIRED TO BE DELIVERED *)
CacheAF = 60000;
BoxElderAF = 60000;
WeberAF = 50000;
JordanAF = 50000;
```

In[24]:=
```
FieldingPump = FieldingPump + powercostadjustment[106 835 000]
WhitesV170 = {WhitesV170[[1]], WhitesV170[[2]] + powercostadjustment[36 197 000]}
WhitesV305 = {WhitesV305[[1]], WhitesV305[[2]] + powercostadjustment[43 502 000]}
WhitesV309 = {WhitesV309[[1]], WhitesV309[[2]] + powercostadjustment[45 711 000]}
WhitesV319 = {WhitesV319[[1]], WhitesV319[[2]] + powercostadjustment[44 722 000]}
WhitesV330 = {WhitesV330[[1]], WhitesV330[[2]] + powercostadjustment[46 180 000]}
WhitesV333 = {WhitesV333[[1]], WhitesV333[[2]] + powercostadjustment[43 889 000]}
WhitesV360 = {WhitesV360[[1]], WhitesV360[[2]] + powercostadjustment[47 184 000]}
WhitesV400 = {WhitesV400[[1]], WhitesV400[[2]] + powercostadjustment[48 255 000]}
WhitesV540 = {WhitesV540[[1]], WhitesV540[[2]] + powercostadjustment[51 454 000]}
WhitesV610 = {WhitesV610[[1]], WhitesV610[[2]] + powercostadjustment[52 622 000]}
TempleFork = {TempleFork[[1]], TempleFork[[2]] + powercostadjustment[2 008 000]}
SWillard = {SWillard[[1]], SWillard[[2]] + powercostadjustment[12 117 500]}
FieldingPumpAdjustment = 187 554 000 - (73 358 000 + powercostadjustment[34 010 000])
```

Out[24]= 2.04893×10^8

Out[25]= $\{170\,000, 3.66547 \times 10^8\}$

Out[26]= $\{305\,000, 3.88973 \times 10^8\}$

Out[27]= $\{309\,000, 3.92261 \times 10^8\}$

Out[28]= $\{319\,000, 3.93021 \times 10^8\}$

Out[29]= $\{330\,000, 3.97146 \times 10^8\}$

Out[30]= $\{333\,000, 3.95263 \times 10^8\}$

Out[31]= $\{360\,000, 4.05303 \times 10^8\}$

Out[32]= $\{400\,000, 4.22558 \times 10^8\}$

Out[33]= $\{540\,000, 4.91736 \times 10^8\}$

Out[34]= $\{610\,000, 5.42493 \times 10^8\}$

Out[35]= $\{41\,000, 1.00335 \times 10^8\}$

Out[36]= $\{55\,000, 4.2976 \times 10^8\}$

Out[37]= 1.08676×10^8

Volume 1 of 2019 Report, page 47: "To develop a reliable annual supply of 220,000 acre-feet during four similar years, reservoir storage of more than 400,000 acre-feet would be needed."

In[38]:=
```
ConvertAFFlowToAFStorage = 400 000 / 220 000;

CacheAF =       CacheAF * ConvertAFFlowToAFStorage;
BoxElderAF = BoxElderAF * ConvertAFFlowToAFStorage;
WeberAF =       WeberAF * ConvertAFFlowToAFStorage;
JordanAF =     JordanAF * ConvertAFFlowToAFStorage;
```

In[43]:=
```
AddToCost[additionalcost_, {{af1_, c1_}, {af2_, c2_}, {af3_, c3_},
    {af4_, c4_}, {af5_, c5_}, {af6_, c6_}, {aftotal_, costtotal_}}] :=
 {{af1, c1}, {af2, c2}, {af3, c3}, {af4, c4}, {af5, c5}, {af6, c6},
  {aftotal, costtotal + additionalcost}}
```

In[44]:=
```
LeastCostOptions[CacheTrueFalse_,
  BoxElderTrueFalse_, WeberTrueFalse_, JordanTrueFalse_] :=
 Module[{NeededAF, thetuples, thetotals, Reservoirs, ReservoirsAndPumpsPipes},
  (* begin module *)
  Cache = CacheTrueFalse; BoxElder = BoxElderTrueFalse;
  Weber = WeberTrueFalse; Jordan = JordanTrueFalse;
  NeededAF = If[Cache, CacheAF, 0] +
    If[BoxElder, BoxElderAF, 0] + If[Weber, WeberAF, 0] + If[Jordan, JordanAF, 0];
  thetuples = Tuples[{{Fielding0, Fielding40, Fielding70},
     {WhitesV0, WhitesV170, WhitesV305, WhitesV309, WhitesV319, WhitesV330,
      WhitesV333, WhitesV360, WhitesV400, WhitesV540, WhitesV610},
     {SWillard0, SWillard}, {CubR0, CubR}, {AboveCutler0, AboveCutler},
     {TempleFork0, TempleFork}}];
  thetotals = Map[Apply[Plus, #] &, thetuples];
  TuplesAndTotals = Diagonal[Outer[Append, thetuples, thetotals, 1]];
  TotalsPosition = 7;
  Reservoirs = Select[TuplesAndTotals, #[[TotalsPosition, AFPosition]] ≥ NeededAF &];
  Export["OutputNewBear0.dat", Reservoirs];
  Print["Number of tuples: ", Length[thetuples],
   " and number satisfying the acre-feet requirement: ", Length[Reservoirs]];
 ReservoirsAndPumpsPipes =
   Map[If[Cache == True && BoxElder == False && Weber == False && Jordan == False &&
      (#[[CubRPosition, AFPosition]] > 0 || #[[AboveCutlerPosition, AFPosition]] > 0 ||
       #[[TempleForkPosition, AFPosition]] > 0) (*then Fielding Pump is unneeded*),
     #, (* else Fielding Pump is needed *)
     If[(#[[CubRPosition, AFPosition]] > 0 || #[[AboveCutlerPosition, AFPosition]] > 0 ||
       #[[TempleForkPosition, AFPosition]] > 0) &&
      #[[WhitesVPosition, AFPosition]] == 0 && #[[FieldingPosition, AFPosition]] > 0,
      AddToCost[FieldingPump - FieldingPumpAdjustment, #], (*else*)
      AddToCost[FieldingPump, #]
     ]] &, Reservoirs];
  Export["OutputNewBear1.dat", ReservoirsAndPumpsPipes];
 ReservoirsAndPumpsPipes = Map[
   If[Cache == False || (#[[CubRPosition, AFPosition]] > 0 && #[[AboveCutlerPosition,
        AFPosition]] > 0 && #[[TempleForkPosition, AFPosition]] > 0),
     #, (* else Pipeline Fielding/Cutler is needed *)
     If[#[[FieldingPosition, AFPosition]] == 40000,
      AddToCost[PipeFieldingCutlerShort, #],
      AddToCost[PipeFieldingCutlerLong, #]]
    ] &,
   ReservoirsAndPumpsPipes];
  Export["OutputNewBear2.dat", ReservoirsAndPumpsPipes];
 ReservoirsAndPumpsPipes =
   Map[If[Weber == True || Jordan == True,
     AddToCost[PipeFieldingWHaven, #], #] &, ReservoirsAndPumpsPipes];
```

```
  Export["OutputNewBear3.dat", ReservoirsAndPumpsPipes];
ReservoirsAndPumpsPipes =
   Map[If[#[[FieldingPosition, AFPosition]] == 0 &&
        (BoxElder || Weber || Jordan ||
          (Cache && (#[[CubRPosition, AFPosition]] == 0 && #[[AboveCutlerPosition,
                AFPosition]] == 0 && #[[TtempleForkPosition, AFPosition]] == 0)))
       ,
       AddToCost[BearRDiversion, #], #] &, ReservoirsAndPumpsPipes];
  Export["OutputNewBear4.dat", ReservoirsAndPumpsPipes];
ReservoirsAndPumpsPipes = Sort[ReservoirsAndPumpsPipes,
    #1[[TotalsPosition, CostPosition]] < #2[[TotalsPosition, CostPosition]] &];
  Export["OutputNewBear5.dat", ReservoirsAndPumpsPipes];
  ReservoirsAndPumpsPipes[[1(*;;10*)]] // TableForm
  (* Fielding WhitesV SWillard CubR AboveCutler TtempleFork *)
 ](* end module *)
```

In[45]:=
```
(* Scenario 1. *)
(* CacheTrueFalse, BoxElderTrueFalse,W eberTrueFalse, JordanTrueFalse *)
LeastCostOptions[True, True, True, True]
SummaryTable = {{1, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}}
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

```
Number of tuples: 528 and number satisfying the acre-feet requirement: 381
```

Out[45]//TableForm=

0	0
400 000	4.22558×10^8
0	0
0	0
0	0
0	0
400 000	1.08875×10^9

Out[46]= $\{\{1, 400\,000, 1.08875 \times 10^9\}\}$

In[47]:=
```
(* Scenario 2. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[False, True, True, True]
SummaryTable = AppendTo[SummaryTable,
  {2, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}]
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

```
Number of tuples: 528 and number satisfying the acre-feet requirement: 458
```

Out[47]//TableForm=

0	0
305 000	3.88973×10^8
0	0
0	0
0	0
0	0
305 000	1.00497×10^9

Out[48]= $\{\{1, 400\,000, 1.08875 \times 10^9\}, \{2, 305\,000, 1.00497 \times 10^9\}\}$

In[49]:=
```
(* Scenario 3. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[True, False, True, True]
SummaryTable = AppendTo[SummaryTable,
   {3, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

Number of tuples: 528 and number satisfying the acre-feet requirement: 458

Out[49]//TableForm=

0	0
305 000	3.88973×10^8
0	0
0	0
0	0
0	0
305 000	1.05517×10^9

In[51]:=
```
(* Scenario 4. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[True, True, False, True]
SummaryTable = AppendTo[SummaryTable,
   {4, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

Number of tuples: 528 and number satisfying the acre-feet requirement: 448

Out[51]//TableForm=

0	0
319 000	3.93021×10^8
0	0
0	0
0	0
0	0
319 000	1.05922×10^9

In[53]:=
```
(* Scenario 5. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[True, True, True, False]
SummaryTable = AppendTo[SummaryTable,
   {5, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

Number of tuples: 528 and number satisfying the acre-feet requirement: 448

Out[53]//TableForm=

0	0
319 000	3.93021×10^8
0	0
0	0
0	0
0	0
319 000	1.05922×10^9

In[55]:=
```
(* Scenario 6. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[False, False, True, True]
SummaryTable = AppendTo[SummaryTable,
   {6, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

Number of tuples: 528 and number satisfying the acre-feet requirement: 486

Out[55]//TableForm=

0	0
305 000	3.88973×10^8
0	0
0	0
0	0
0	0
305 000	1.00497×10^9

In[57]:=
```
(* Scenario 7. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[False, True, False, True]
SummaryTable = AppendTo[SummaryTable,
   {7, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

Number of tuples: 528 and number satisfying the acre-feet requirement: 482

Out[57]//TableForm=

0	0
305 000	3.88973×10^8
0	0
0	0
0	0
0	0
305 000	1.00497×10^9

In[59]:=
```
(* Scenario 8. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[False, True, True, False]
SummaryTable = AppendTo[SummaryTable,
   {8, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

Number of tuples: 528 and number satisfying the acre-feet requirement: 482

Out[59]//TableForm=

0	0
305 000	3.88973×10^8
0	0
0	0
0	0
0	0
305 000	1.00497×10^9

In[61]:=
```
(* Scenario 9. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[True, False, False, True]
SummaryTable = AppendTo[SummaryTable,
   {9, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

```
Number of tuples: 528 and number satisfying the acre-feet requirement: 482
```

Out[61]//TableForm=

0	0
305 000	3.88973×10^8
0	0
0	0
0	0
0	0
305 000	1.05517×10^9

In[63]:=
```
(* Scenario 10. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[True, False, True, False]
SummaryTable = AppendTo[SummaryTable,
   {10, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

```
Number of tuples: 528 and number satisfying the acre-feet requirement: 482
```

Out[63]//TableForm=

0	0
305 000	3.88973×10^8
0	0
0	0
0	0
0	0
305 000	1.05517×10^9

In[65]:=
```
(* Scenario 11. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[True, True, False, False]
SummaryTable = AppendTo[SummaryTable,
   {11, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

```
Number of tuples: 528 and number satisfying the acre-feet requirement: 477
```

Out[65]//TableForm=

0	0
305 000	3.88973×10^8
0	0
0	0
0	0
0	0
305 000	6.55748×10^8

In[67]:=
```
(* Scenario 12. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[False, False, False, True]
SummaryTable = AppendTo[SummaryTable,
   {12, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

Number of tuples: 528 and number satisfying the acre-feet requirement: 516

Out[67]//TableForm=

70 000	169 527 000
0	0
0	0
0	0
0	0
41 000	1.00335×10^8
111 000	7.65499×10^8

In[69]:=
```
(* Scenario 13. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[False, False, True, False]
SummaryTable = AppendTo[SummaryTable,
   {13, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

Number of tuples: 528 and number satisfying the acre-feet requirement: 516

Out[69]//TableForm=

70 000	169 527 000
0	0
0	0
0	0
0	0
41 000	1.00335×10^8
111 000	7.65499×10^8

In[71]:=
```
(* Scenario 14. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[False, True, False, False]
SummaryTable = AppendTo[SummaryTable,
   {14, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

Number of tuples: 528 and number satisfying the acre-feet requirement: 509

Out[71]//TableForm=

70 000	169 527 000
0	0
0	0
0	0
0	0
41 000	1.00335×10^8
111 000	3.66079×10^8

In[73]:=
```
(* Scenario 15. *)
(* CacheTrueFalse, BoxElderTrueFalse, WeberTrueFalse, JordanTrueFalse *)
LeastCostOptions[True, False, False, False]
SummaryTable = AppendTo[SummaryTable,
   {15, %[[TotalsPosition, AFPosition]], %[[TotalsPosition, CostPosition]]}];
(* Fielding WhitesV SWillard CubR AboveCutler TempleFork *)
```

```
Number of tuples: 528 and number satisfying the acre-feet requirement: 509
```

Out[73]//TableForm=

70 000	169 527 000
0	0
0	0
0	0
0	0
41 000	1.00335×10^8
111 000	3.20057×10^8

In[75]:=
```
writeWithoutExponent[number_] :=
 ToString[NumberForm[number, ExponentFunction -> (If[-20 < # < 20, Null, #] &)]]
Transpose[MapAt[Map[writeWithoutExponent, #] &, Transpose[SummaryTable], 3]];
TableForm[%]
Export["OutputNewBear6.dat", %]
```

Out[77]//TableForm=

1	400 000	1088752126.
2	305 000	1004972732.
3	305 000	1055167732.
4	319 000	1059215733.
5	319 000	1059215733.
6	305 000	1004972732.
7	305 000	1004972732.
8	305 000	1004972732.
9	305 000	1055167732.
10	305 000	1055167732.
11	305 000	655747732.
12	111 000	765498507.
13	111 000	765498507.
14	111 000	366078507.
15	111 000	320056891.

Out[78]= OutputNewBear6.dat