Integrating Climate Change Considerations into Environmental Assessments of Hydro-electric Power Projects in Eastern and Northern Canada

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Abstract

This research project investigated the merits and justification of whether greenhouse gas (GHG) climate change considerations should be integrated into environmental impacts assessments of hydro-electric projects in the north and east of Canada. To this end, research was conducted on basin hydrology and river flow for several Canadian drainage basins in northern Manitoba (Grass River), Newfoundland- and-Labrador (Eagle River) and Québec (Grande-Baleine, Vermillon and Sainte-Marguerite), for two time slices, one current (1961-1990) and one future (2040-2069). The methodologies used consisted of coupling downscaled temperature and precipitation outputs of two atmosphere-ocean general circulation models (AOGCM), one Canadian (CGCM 1) and the other British (HadCM3) to the Thornthwaite water budget (Grande-Baleine, Grass River, Eagle River) and the Streamflow Synthesis and Reservoir Regulation (SSARR) hydrological models (Grande-Baleine, Vermillon and Sainte-Marguerite). The results show that in general, the timing of peak spring discharge occurs earlier by a few days to more than a month, changes in total discharge volume, phase shifts of river discharge and increased inter-annual variability of discharge, depending on river basin and climate scenario. However, given the high level of uncertainty of climate scenarios, it is judged that it may be premature to integrate climate change considerations into environmental assessments of hydro-electric projects. All the same, climate change and variability may significantly influence the practice of environmental impacts assessments.

Introduction

The purpose of an environmental impact assessment (EIA) is to ensure that the development options under consideration are environmentally sound and sustainable, and that any environmental consequences are recognized early in the project cycle and taken into account in project design. EIAs are done so as to identify ways of improving projects environmentally, and minimizing, mitigating, or compensating for adverse impacts. The process also provides a formal mechanism for inter-agency coordination and for addressing concerns of affected groups and local non-governmental organizations (NGOs).

Furthermore, EIA is a process whose breadth, depth, and type of analysis depend on the nature, scale, and potential environmental impact of the proposed project, and in the case of the anticipated impacts of climate change, the potential environmental impact on the proposed project. EIAs should conceivably take into account the natural environment, and changes to the natural environment brought about by climate change; human health and safety and social aspects, such as involuntary resettlement, indigenous peoples, and cultural property.

Climate change has been recognized internationally and by the federal, provincial and territorial governments in Canada as an important environmental issue. EA has the potential to link project planning to the broader management of climate change issues in Canada. Members of the public and government agencies have raised questions and expressed interest in how climate change is, and should be considered in project reviews.

Jurisdictions expect that the consideration of climate change in project EAs will be consistent with broader climate change policy, increase attention to, and awareness of, GHG emissions from projects subject to EA, stimulate consideration of less emission-intensive ways to design and operate projects, help proponents manage or reduce the potential risks associated with climate change impacts on projects and assure the public that climate change considerations are being taken into account.

Incorporating climate change considerations in EA can help to determine whether projects are consistent with jurisdictional actions and initiatives to manage GHG emissions, such as under the *Climate Change Plan for Canada*. It can also assist proponents in using best practices that adapt to possible climate change impacts, such as changes in the frequency or intensity of extreme weather events, increases in mean temperatures or altered precipitation patterns and amounts.

Jurisdictions recognize that our understanding of climate change and its implications is still developing (CEAA, 2003). Furthermore, there are currently no legal requirements or clearly sanctioned benchmarks for GHG emission reductions. Similarly, the assessment of potential climate change impacts and the identification of effective adaptation responses are new and evolving fields in which more research is required. While our understandings and policies are advancing, it is still useful that project proponents and government EA practitioners and decision makers be aware of any important climate change implications related to proposed projects. Potential risks to the project, providing they do not affect the public, public resources, the environment, other businesses or individuals, may be borne by the project proponent and are not generally a concern for jurisdictions.

Normally, projects are designed with some assumption about the climate in which it will function. The conventional way is to assume that the climate of the past is a reliable guide to the future. Given the possibility of climate change and variability in the future, this assumption may no longer hold. Thus design criteria must be based on probable future environmental conditions, including climate change, over the life of the project. Accordingly, Environmental Impact Assessments of projects and activities should consider not only the effects of the project on the environment, but also the impacts of impending climate-related changes on the project or activity, namely the impacts of the environment on the project. To determine the risks to which different sectors are exposed it is necessary to examine their vulnerability to specific hazards. Potential hazards expected from climate variability and climate change include: increased near-surface temperatures, increased/decreased precipitation and its variability, more frequent and intense storms, changing weather patterns and sea level rise. Among the sectors with greatest vulnerability are water resources, agriculture, and biodiversity.

When considering the impacts of climate change, the EIA process evaluates a project's potential environmental risks and impacts in its area of influence; identifies and evaluates potential impacts from climate change on the project's area of influence; examines project alternatives; identifies ways of improving project selection, siting, planning, design, and implementation by preventing, minimizing, mitigating, or compensating for adverse environmental impacts and anticipated adverse impacts from climate change, and enhancing positive impacts; and includes the process of mitigating and managing adverse environmental impacts and anticipated adverse impacts from climate change throughout project implementation. In addressing anticipated adverse impacts from climate change, the implementation of appropriate adaptation planning and management mechanisms must be considered.

In view of the fact that certain projects have life cycles that extend well into the future and that climate, including its variability, is expected to change in the foreseeable future, EAI practitioners are now being asked to integrate climate change considerations into EAs, where applicable.

Lee (2001) undertook a detailed review of projects in Canada in which consideration was given to climate change issues. Amongst these projects were: Diavik Diamond Mines, Cascade Heritage Power Park, Confederation Bridge (Fixed Link – Northumberland Strait), decommissioning of the Quirke and Panel Uranium Mines at Elliot Lake, Little Bow Reservoir/Highwood Diversion and dredging of the St. Lawrence River between Montreal and Cap à la Roche. Furthermore, Barrow and Lee (2000) provided a detailed document on Guidance for integrating climate change into EAs. More recently, the Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment (CEAA, 2003) produced a General Guidance for practitioners for incorporating climate change considerations in EAs.

In general, two practical approaches for incorporating climate change considerations in EA are being proposed:

1. Greenhouse Gas (GHG) Considerations: where a proposed project may contribute to GHG emissions.

2. Impacts Considerations: where climate change may affect a proposed project.

The focus of this paper is on the second issue, namely the extent to which large hydro-electric power projects may be influenced by climate change over their life cycle. Furthermore, in the light of our data analyses, the issue of whether there is sufficient justification for the inclusion of climate change considerations in EAs of such projects is also raised.

Objectives of Research Project

The main objectives of the proposed research project are to develop appropriate methodologies and guidelines, based on the results of the proposed research, to facilitate the integration of climate change considerations into environmental assessments of hydropower and similar projects. A further objective would be to assess the impacts of greenhouse gas climate change on the climate and hydrology of drainage basins that are exploited for hydro-electric power generation in Eastern and Northern Canada and to demonstrate that large-scale climate change need to be integrated in the engineering design and environmental assessments of projects such as the creation of hydropower dams.

Methodology

Although, not a typical EIA project, the study did integrate a number of the essential elements of a generic EIA (Lindsay and Smith, (2001), namely project description and screening, project scoping and identification of potential impacts, identification of project alternatives, evaluation of significant impacts and public input. However, the focus of the study was to evaluate and report significant findings relating to the potential impacts of the environment, namely climate change and variability, on the project, in this case hydro-electric power plants.

The methodology of the research project basically involves coupling climate change scenarios with two different hydrological models, namely the SSARR (Streamflow Synthesis and Reservoir Regulation) and the Thornthwaite Water Budget (WATBUG) (Thornthwaite and Mather, 1957; Black, 1996) models, so as to assess future changes in such basin hydrology responses as net basin supply, river discharge and likely maximum flood events.

Scenarios of climate change are derived from two AOGCMs, namely the Canadian CGCM2 and the British HadCM3. Two scenarios of climate, each spanning 30 years are considered: one current (1961-1990) and a future time slice (2040-2069). Because of scaling problems, the required diagnostics of the coarse AOGCM's, namely surface level maximum and minimum air temperature and precipitation are downscaled, for the three Quebec drainage basins using the Statistical DownScaling Method (SDSM) (Wilby et al. ; 2002)

The study covers three drainage basins in Québec, spanning from south (Vermillon: 47°39' N, 72°56' W; Sainte-Marguerite : 50°09' N, 66°36' W), to north (Grande Baleine: 55°16' N, 77°47' W) that contain hydropower installations. Two other drainage basins in northern Manitoba (Grass River: 55°74'N, 97°00'W), Newfoundland- and-Labrador (Eagle River: 55°53'N, 57°49'W) are also studied. Locations and areas of the selected drainage basins are provided in Table 1)

For the Québec drainage basins, the downscaled climate parameters are then be coupled to the SSARR hydrological model, so as to determine current (1961-1990) and future

(2040-2069), when effective CO_2 would have doubled, hydrological characteristics of the selected drainage basins, including mean daily and monthly net basin supply, reservoir levels, discharge and likely maximum floods.

Similarly, scenarios of climate change are derived from two the AOGCMs, namely the Canadian CGCM2 and the British HadCM3, each spanning 30 years, one current (1961-1990) and one future (2040-2069) are coupled to the WATBUG model for estimating river basin discharge. However, in this case, no downscaling of the GCM data is done. Instead the nearest grid point of each GCM with respect to the drainage basins is used. This approach seems appropriate for the larger drainage basins in Northern Manitoba and in Churchill-Labrador.

In the case of WATBUG, for each drainage basin, water surplus is distributed over the entire year, using the methodology suggested by Black (1996), so as to capture the monthly evolution of river discharge, depending on temperature and precipitation. The calibration is done for the current (1961-1990) period and these same tuning parameters are retained when applied to the future (2040-2069) climate.

Results

At first we present the results for the three Quebec drainage basins starting with the Vermillon River basin, for which the simulated daily discharge derived by coupling the SSARR hydrological model with downscaled CGCM1 data, is compared with daily observed data (Figure 1 and Table 2). In Figure 1, it is evident that the simulated daily discharge consistently underestimates relative to the observed daily discharge. This would indicate that the SSARR calibration for this drainage basin has to be further tuned to reduce this difference. Furthermore, the difference between mean simulated daily discharge is greatest (-31.4 %) in winter and least (-23.1 %) in spring (Table 2).

When comparing future (2040-2069) daily discharge with current observed (196-1990), it is observed that future daily discharge, in general, exceeds current discharge, especially during the spring peak discharge period (Figure 2). Furthermore, apart from the increase (7.5 %) in mean daily discharge for the future climate the variability in daily discharge also increases under the future climate as shown by the greater difference between minimum and maximum daily discharge and by the increased standard deviation (21.8 %) of daily discharge: minimum daily discharge increases slightly (5.4 %), but maximum daily discharge increases substantially (30.2 %) (Table 3). Furthermore, the greatest increase in daily discharge occurs during spring (18.2 %) (Table 4). However, the timing of peak spring discharge is not shifted to earlier, as would be expected (Figure 2). Also, mean daily discharge decreases under the future climate scenario during summer (-6.1 %) (Table 4). This type of result is in line with future climate warming in that higher temperatures are expected in winter which would lead to earlier spring melt and higher discharge. On the other hand greater evaporation rates under the future warmer climate can lead to decreases in summertime discharge.

Somewhat contrasting results are however obtained for the Sainte-Marguerite River basin. In this instance future mean daily discharge is generally less, although, as to be expected, peak spring discharge occurs earlier by about ten days (Figure 3). This result is due to the decrease in late winter and early spring precipitation for this location under the CGCM1 future climate scenario (Singh et al., 2003). Furthermore, apart from the slight decrease (-8.5 %) in mean daily discharge under the future climate scenario, there is an accompanying decrease in the variability of mean daily discharge as reflected by the decrease in the standard deviation (-12.7 %) (Table 5). Also, minimum (-5.9 %) and maximum (2.3 %) change minimally under the future climate scenario (Table 5). However, as was the case for the Vermillon River basin, the greatest increase in daily discharge occurs during spring (49.9 %) and the greatest decrease in summer (-23.5 %). (Table 6). Again, these results, for the Sainte-Marguerite River basin, would reflect an increase in late winter and early spring temperatures, thereby provoking earlier snowmelt and an increase in summertime evaporation, thereby leading to a decrease in discharge.

The results for the Grande-Baleine River basin are very similar to those of the Sainte-Marguerite River basin. For this drainage basin too, there is an overall decrease (-8.8 %) in mean discharge (Figure 4 and Table 7). Also the timing of both the onset of springmelt and peak discharge occur earlier by about two weeks (Figure 4). Apart from the overall decrease (-8.8 %) in daily discharge, there is a corresponding decrease in the variability of daily discharge under the future climate scenario as reflected by the decrease in the standard deviation (-19.9 %), the minimal change in minimum daily discharge and the decrease in maximum daily discharge (-20.6 %) (Table7). Again however, it would seem that the greatest increase in daily discharge occurs during spring (32.5 %) and the greatest decrease during summer (-15.1 %) (Table 8). As in the case of the previous drainage basins these conditions may be linked to the projected warming under the future climate scenario, causing earlier spring melt and higher evaporation and decreased discharge in summer.

We next look at the changes in monthly river basin discharge using the coupling of WATBUG with both the Canadian (CGCM1) and the British (HadCM3) scenarios. For purposes of comparison, we at first examine the Grande-Baleine River basin. As opposed to the results obtained by coupling the SSARR hydrological model with CGCM1 data, the WATBUG coupled with CGCM1 data approach gives a slight increase (4 %) in mean discharge for the future (2040-2069) climate as opposed to the current (1961-1990) climate (Figure 5 and Table 9). Furthermore, unlike the previous method, the variability of monthly discharge increases slightly, as expressed by the standard deviations of the current (1961-1990) and the future (2040-20690 climate, when using the WATBUG approach (Table 9). However, it would seem that there is agreement with the SSARR coupled with the timing of the onset and the peak of spring discharge, occurring earlier by about two weeks and a higher peak discharge (Figure 5). Also, as was observed with the previous method, the WATBUG approach also shows a tendency to slightly decreased discharge during the summer months under the future (2040-2069) climate (Figure 5). When coupling WATBUG with HadCM3 data however, the results show a much greater increase (14 %) in mean discharge under the future HadCM3 future climate scenario. It must be cautioned though, that these data are limited by the gross underestimation of current (1961-1990) discharge (Figure 6 and Table 10). However, like the results with the CGCM1 scenario, when using the HadCM3 scenario, the onset of spring discharge occurs by about two weeks earlier, peak spring discharge is much higher and the variability of monthly discharge as expressed by the standard deviation is much higher under the future climate (2040-2069) (Figure 6 and Table 10).

Next, we examine the changes in mean monthly discharge for the Grass River basin in Northern Manitoba. When coupling WATBUG with the CGCM1 climate scenarios, we observe that here also there is a minimal increase (1 %) in mean discharge, a slightly earlier onset and higher peak of spring discharge and a slight decrease in summertime discharge for the future climate (2040-2069), as compared to the current (1961-1990) climate (Figure 7 and Table 11). Also, there is little or no change in discharge variability as represented by the standard deviation under the future CGCM1 climate scenario (Table 11). When coupling WATBUG with the HadCM3 climate scenarios however, similar results are obtained, namely, there is a small increase (15 %) in mean discharge, a slightly earlier onset and higher peak of spring discharge and a general decrease in summertime discharge for the future climate (2040-2069), as compared to the current (1961-1990) climate (Figure 8 and Table 12). However, in this case, there is a relatively higher change in discharge variability as represented by the standard deviation under the future HadCM3 climate scenario (Table 12).

Finally we examine the changes in mean monthly discharge for the Eagle River basin in Newfoundland and Labrador.

At first, when coupling WATBUG with the CGCM1 climate scenarios, we observe that there is a substantial increase (22 %) in mean discharge, a much earlier onset, of about two weeks and a much higher peak of spring discharge and an increase in summertime discharge for the future climate (2040-2069), as compared to the current (1961-1990) climate (Figure 9 and Table 13). Furthermore, there is a significant change in discharge variability as represented by the standard deviation under the future CGCM1 climate scenario (Table 13). However, when coupling WATBUG with the HadCM3 climate scenarios, somewhat dissimilar results are obtained: although there is a small increase (2 %) in mean discharge and a slightly earlier onset of spring discharge, also by about two weeks, there is a decrease in peak spring discharge and a general decrease in summertime discharge for the future climate (2040-2069), as compared to the current (1961-1990) climate (Figure 10 and Table 14). Also, in this case, there is little or no change in discharge variability as represented by the standard deviation under the future HadCM3 climate scenario (Table 14).

Discussion

It is apparent from the previous section that the results on the changes in river basin discharge between the current (1961-1990) and the future (2040-2069) would seem to vary and be inconsistent, depending on the river basin in question and the climate scenario and the hydrological used. For instance, when coupling the SSARR hydrological model with the CGCM1 scenario future (2040-2069) peak spring discharge increases for the Vermillon River basin, but decreases for the Sainte-marguerite and Grande-Baleine River basins. On the other hand, by coupling the WATBUG hydrological model with both the CGCM and HadCM3 climate scenarios and applying them to the Grande-Baleine River basin, we obtain somewhat conflicting results. As opposed to the SSARR hydrological model, the WATBUG model coupled to the CGCM1 climate scenario gave increasing, instead of decreasing discharge for the future (2040-2069), as opposed to the current (1961-1990) climate. Furthermore, when WATBUG is coupled to both the CGCM1 and HadCM3 climate scenarios and applied to the Grande-Baleine River basin, the differences in monthly discharge and peak spring discharge are greater for the future (2040-2069), as opposed to the current (1961-1990) climate when using the HadCM3 scenario. It must be noted though that the Had CM3 simulations for the current climate underestimates relative to observed data. Similarly for the Eagle River drainage basin, using the coupling to the WATBUG hydrological model, the CGCM1 climate scenario gave an increase in peak discharge whereas the HadCM3 model gave a decrease in peak spring for the future (2040-2069) climate relate to the current (1961-1990) climate.

What seems to be consistent, across different climate scenarios, hydrological models and drainage basins, is the fact that the onset of spring peak discharge is advanced by about two weeks and, in general, peak spring discharge is greater under the future (2040-2069) climate as opposed to the current (1961-1990) climate.

However, these results have to be considered in the light of the spatial and temporal scales of the two approaches used to couple hydrological models to AOGCM diagnostics: for the SSARR model downscaled daily data is used, whereas in the case of the WATBUG model nearest-point large-scale AOGCM monthly data is used.

Conclusions and Recommendations

These results and arguments were presented in a workshop to a panel of experts consisting of research (Universities, Ouranos), government officials (Federal and Provincial) and private (Hydro-Quebec) representatives. They were asked that given the cascade of uncertainties inherent in A-OGCM climate models and scenarios (McCarthty et al., 2001) and the results obtained as described above, whether it is justifiable to incorporate climate change considerations into the EA process and methodology relating to hydro-power projects.

The conclusions derived was that given the uncertainties in climate change scenarios and the results presented, it may be premature to consider integrating climate change considerations into the environmental assessments of hydro-power projects and that for the time being climate change issues should be looked at in the context of regional and strategic environmental assessment procedures, as suggested by Noble (2002).

The panel also concluded that the research did address a number of issues pertinent to the EA process and the implications of climate change, especially in regards to hydro-power projects in Northern Canada.

References

Barrow, E.M. and R.J. Lee (2000). Climate Change and Environmental Assessment Part 2 : Climate Change Guidance for Environmental Assessments . **The Canadian Institute for Climate Studies : Research and Development Monograph Series :**111p

Black, P.E. (1996). **The Thornthwaite Water Budget: Professional Version**. SUNY College of Environmental Science and Forestry, Syracuse,NY.

CEAA (Canadian Environmental Assessment Agency) (2003). **Incorporating Climate Change Considerations in Environmental Assessments ; General Guide for Practitioners.** Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment.: 44 p.

Lee,R.J.(2001). Climate Change and Environmental Assessment, Part 1 : Review of Climate Change Considerations in Selected Past Environmental Assessments. **The Canadian Institute for Climate Studies :**80p

Lindsay, K.M. and D.W. Smith (2001). Review of Environmental Assessment Processes. **Canadian Circumpolar Institute (CCI) Press Occasional Publication No. 50** : 30p.

McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White (2001). **Climate Change 2001 : Impacts, Adaptation and Vulnerability. Contribution of Working Group 11 to the Third Assessment Report of the Intergovernmental Panel on Climate Change.** Cambridge University Press, Cambridge, UK :1032 p.

Noble, B.M (2002). Strategic environmental assessment of Canadian energy policy. **Impact Assessment and Project Appraisal**. Vol. 20 (3): 177-188.

Singh, B., S. Gagnon, N. Davey, J. Rousselle and S. Weyman (2003). Intégrer les considérations reliées au changement climatique dans l'évaluation environnementale des projets hydroélectriques de lest et du nord du Canada. **Rapport : l'Agence Canadienne d'Évaluation Environnementale;** 125p.

Thornthwaite, C.W. and J.R. Mather (1957). The Water Balance. **Publications in Climatology**. Vol. VIII, No.1.

Wilby, R. L., C.W. Dawson and E. Barrow (2002). SDSM – a decision support tool for the assessment of regional climate change impacts. **Environmental Modelling and Software**. Vol 17 ; 147-159.

Table 1 : Locations and sizes of drainage basins

Drainage Basin	Location	Area
Vermillon	47°39'N, 72°56'W	2 630 km^2
Sainte-Marguerite	50°09'N, 66°36'W	6 177 km^2
Grande Baleine	55°16'N, 77°47'W	36 300 km^2
Grass River	55°74'N, 97°00'W	15 400 km^2
Eagle River	55°53'N, 57°49'W	10 900 km^2

Table 2 : Mean Seasonal Discharge (m3/s) for the Vermillon River Basin (1961-1990)

	Observed Mean Discharge (m3/s)	Simulated Mean Discharge (m3/s)
Spring	75.8	58.3
Summer	41.3	31.2
Autumn	31.6	23.1
Winter	20.7	14.2

Table 3 : Characteristics of the simulated discharge (m3/s) for the Vermillon River basin

	1961-1990	2040-2069	Difference (%)
Mean (m3/s)	31.8	34.2	+ 7.5
Standard Deviation(m3/s)	36.9	44.9	+ 21.8
Minimum (m3/s)	9.3	9.8	+ 5.4
Maximum (m3/s)	367.0	478.0	+ 30.2

Table 4 : Simulated seasonal discharge (m3/s) for the Vermillon River basin

	1961-1990 (m3/s)	2040-2069 (m3/s)	Difference (%)
Spring	58.3	68.9	+ 18.2
Summer	31.2	29.3	- 6.1
Autumn	23.1	23.5	+1.7
Winter	14.2	14.6	+ 2.8

Table 5 : Characteristics of the simulated discharge (m3/s) for the Sainte-Marguerite River basin

	1961-1990	2040-2069	Difference (%)
Mean (m3/s)	154.2	141.0	-8.5
Standard Deviation (m3/s)	233.0	203.4	-12.7
Minimum (m3/s)	27.0	25.4	-5.9
Maximum (m3/s)	1760.0	1800.0	2.3

Table 6 : Simulated seasonal discharge (m3/s) for the Sainte-Marguerite River basin

	1961-1990 (m3/s)	2040-2069 (m3/s)	Différence (%)
Spring	72.7	109.0	+ 49.9
Summer	377.8	289.1	- 23.5
Autumn	122.2	123.3	+ 0.9
Winter	41.4	37.0	- 9.7

Table 7 : Characteristics of the simulated discharge (m3/s) for the Grande-Baleine River basin

	1961-1990	2040-2069	Différence (%)
Mean (m3/s)	640.2	584.1	- 8.8
Standard Deviation (m3/s)	523.9	419.4	-19.9
Minimum (m3/s)	121.0	121.0	0.0
Maximum (m3/s)	2910.0	2310.0	-20.6

Table 8 : Simulated seasonal discharge (m3/s) for the Grande-Baleine River basin

	1961-1990 (m3/s)	2040-2069 (m3/s)	Différence (%)
Spring	167.9	222.5	+ 32.5
Summer	1285.6	1091.0	- 15.1
Autumn	767.1	692.4	- 9.7
Winter	304.9	326.0	+ 6.9

Table 9 : Statistics on the variability of mean monthly discharge (m^3s^{-1}) for Grande Baleine for the 1961-90 and 2040-69 time periods (CGCM10)

	N	Minimum	Maximum	Mean	Standard Deviation
CGCM1 (1961-90)	360	196	2210	558	420
CGCM1 (2040-69)	360	178	2123	582	435

Table 10 : Statistics on the variability of mean monthly discharge (m^3s^{-1}) for Grande-Baleine for the 1961-90 and 2040-69 time periods (HadCM3).

	N	Minimum	Maximum	Mean	Standard Deviation
HadCM3 (1961-90)	360	83	1344	279	174
HadCM3 (2040-69)	360	29	1484	323	244

Table 11 : Statistics on the variability of mean monthly discharge (m^3s^{-1}) for GraS River for the 1961-90 and 2040-69 time periods (CGCM1)

	N	Minimum	Maximum	Mean	Standard Deviation
CGCM1 (1961-90)	360	16	337	80	52
CGCM1 (2040-69)	360	20	324	81	53

Table 12 : Statistics on the variability of mean monthly discharge (m^3s^{-1}) for Grass River for the 1961-90 and 2040-69 time periods (HadCM3)

	N	Minimum	Maximum	Mean	Standard Deviation
HadCM3 (1961-90)	360	14	760	126	118
HadCM3 (2040-69)	360	34	880	149	135

Table 13 : Statistics on the variability of mean monthly discharge (m^3s^{-1}) for Eagle River for the 1961-90 and 2040-69 time periods (CGCM1)

	N	Minimum	Maximum	Mean	Standard Deviation
CGCM1 (1961-90)	360	42	826	214	194
CGCM1 (2040-69)	360	42	1130	274	257

Table 14 : Statistics on the variability of mean monthly discharge (m^3s^{-1}) for Eagle River for the 1961-90 and 2040-69 time periods (HadCM3)

	N	Minimum	Maximum	Mean	Standard Deviation
HadCM3 (1961-90)	360	42	993	199	193
HadCM3 (2040-69)	360	42	891	204	188

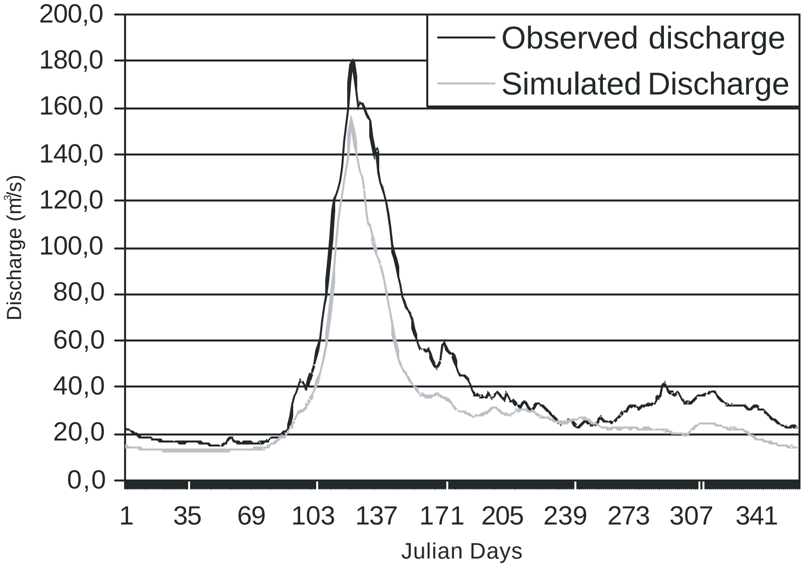

Figure 1: Flood Hydrograph for the Vermillon River basin (1961-1990)

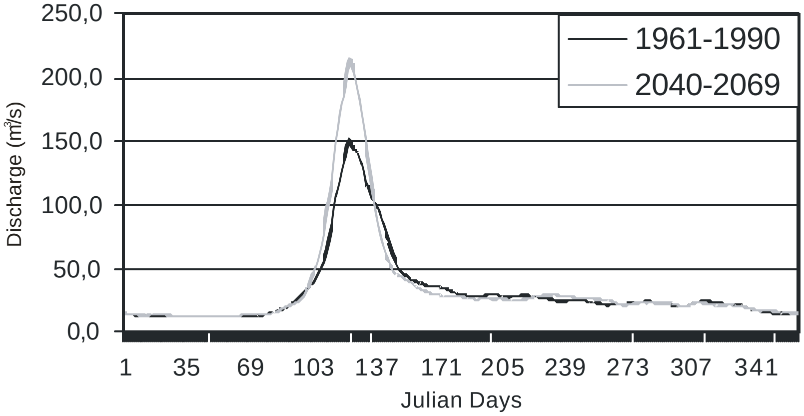

Figure 2: Comparison between current and future discharge for the Vermillon River basin

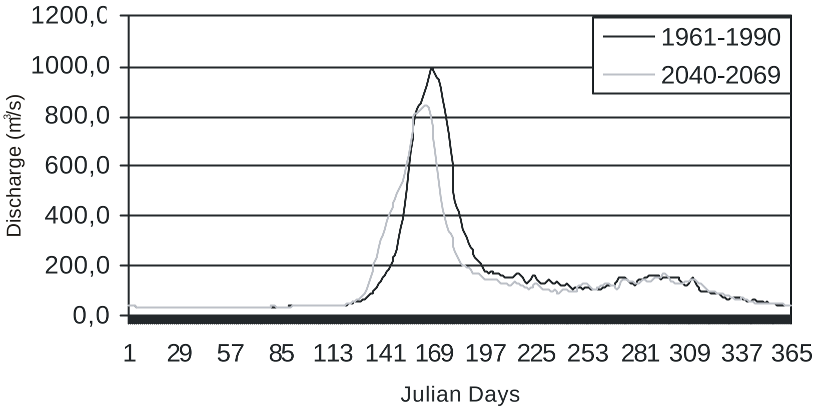

Figure 3: Comparison between current and future discharge for the Sainte-Marguerite River basin

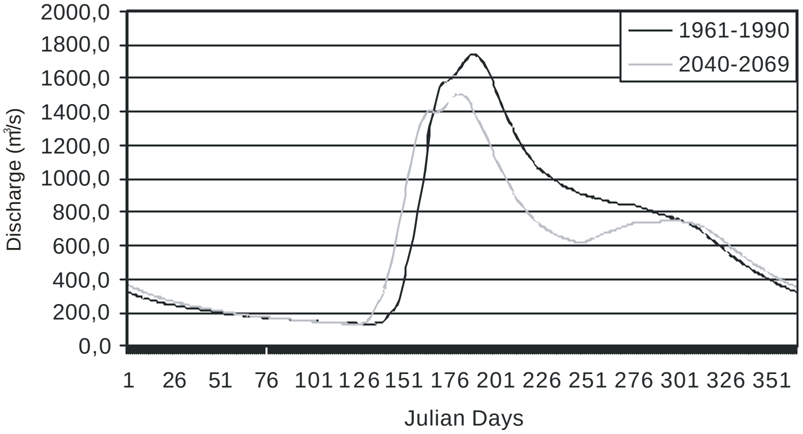

Figure 4: Comparison between current and future discharge for the Grande-Baleine River basin

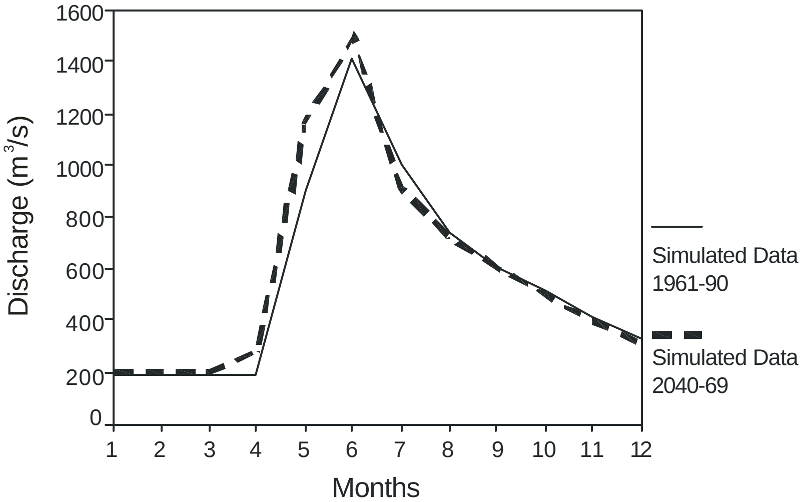

Figure 5. Variations of mean monthly discharge (m^3/s) of the Grande-Baleine river basin for the periods 1961-90 and 2040-69 according to CGCM1.

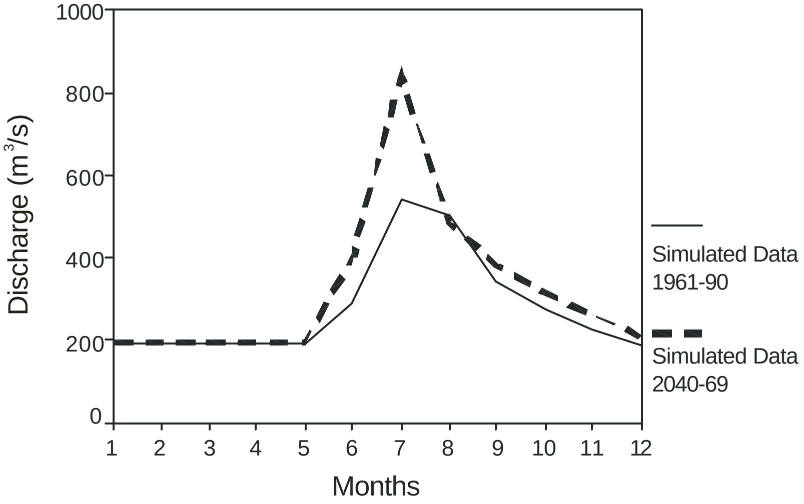

Figure 6. Variations of mean monthly discharge (m^3/s) of the Grande-Baleine river basin for the periods 1961-90 and 2040-69 according to HadCM3.

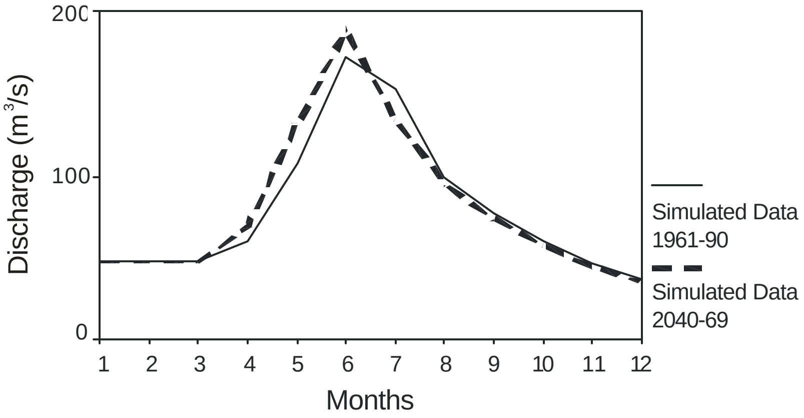

Figure 7. Variations of mean monthly discharge (m^3/s) of the Grass River basin for the periods 1961-90 and 2040-69 according to CGCM1.

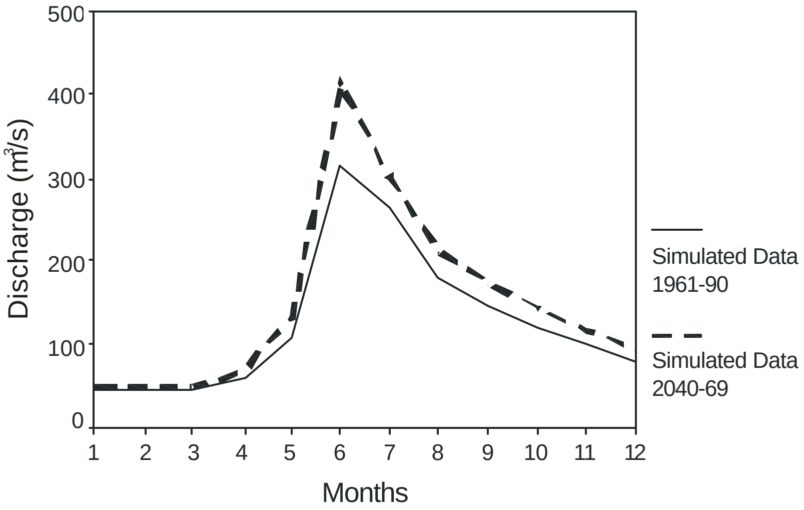

Figure 8. Variations of mean monthly discharge (m^3/s) of the Grass River basin for the periods 1961-90 and 2040-69 according to HadCM3.

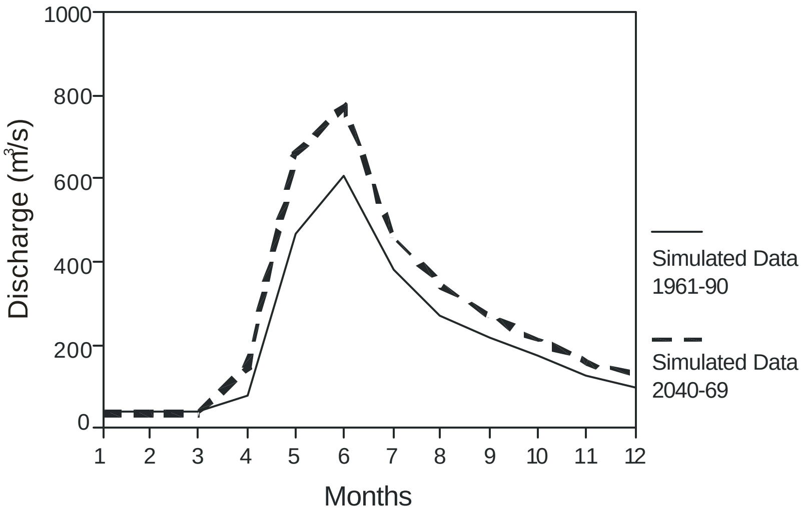

Figure 9. Variations of mean monthly discharge (m^3/s) of the Eagle River basin for the periods 1961-90 and 2040-69 according to CGCM1

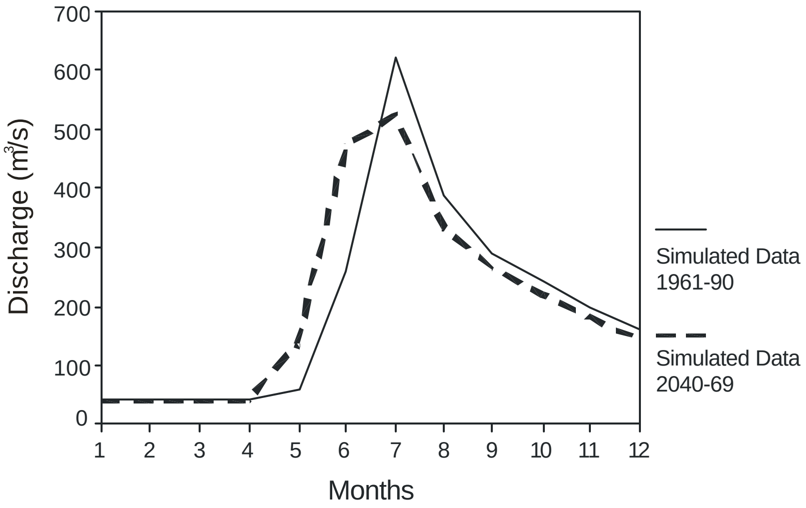

Figure 10. Variations of mean monthly discharge (m^3/s) of the Eagle River basin for the periods 1961-90 and 2040-69 according to HadCM3